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ON THE APPLICATION OF CHEMISTRY TO ARCHAEOLOGY

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INTRODUCTION

Archaeology may be defined as the science which yields information and develops theories about past human activity by means of a study of ancient material remains. As a general rule the archaeologist is much more interested in the form or style of such remains than in their chemical composition, for this may often have little or no archaeological significance. For example, the form of flint implements may be an important index to the cultural status of a certain group of early people, but it is improbable that any significant information from the standpoint of archaeology could be obtained from an investigation of the chemical composition of the flint of such implements. But sometimes important archaeological information may be obtained by a study of the chemical composition of material remains. This information may supplement that obtained from a study of form or style, or it may be entirely new information not otherwise obtainable. The purpose of the present paper is to indicate by means of general categories, specific illustrative examples, and a select bibliography how chemical facts, methods, and theories have been and may continue to be applied to the study of the material remains of past human activity for the purpose of furthering archaeological science. Also indicated are miscellaneous ways in which chemistry may be useful to the field and to the museum archaeologist. For the most part the illustrative examples are based upon the writer's own experience, though some mention is made of pertinent work of other investigators.

THE IDENTIFICATION OF MATERIALS

Perhaps the simplest and most obvious application of chemistry to archaeology is the exact qualitative identification of materials in order that these may be accurately described in archaeological publications. The accurate identification of materials is important also because significant interpretations may depend upon the exact nature of certain materials. Errors of identification, some of them rather glaring from the chemical viewpoint, are not infrequent in the older archaeological literature, and are by no means absent from some of the recent literature. Copper is sometimes confused with bronze, bronze with brass, lime mortar with gypsum plaster, solid bitumens with vegetable resins, and so on for other materials superficially similar. Such confusions have arisen either because no proper identification of a material was ever made in the first place or because the archaeologist, even after a correct identification had been made, did not then appreciate the importance of the chemical distinction between certain materials very similar in appearance and put to similar uses. Actually, the inexact or loose identification of the kinds of materials found in excavations may lead to serious error. For example, it might not seem important to determine whether a given object is composed of brass or of bronze, but a very wrong conclusion as to time of manufacture could be reached by a failure to determine which it is, or a failure to appreciate the significance of the distinction, brass having been first made about the middle of the first century B. C. and bronze some twenty centuries earlier.

Though a few materials, such as wood, may be readily recognized, and even identified as to variety, by means of physical appearance alone, it is unsafe as a general rule to rely solely on physical properties for the identification of ancient materials. Even when the material of an object may be recognized by simple inspection, the application of chemical tests may be very desirable both to confirm and to amplify the observation. For example, there is generally no difficulty in recognizing an ancient iron object as such even when it is in the usual highly oxidized condition, but for iron objects of early date it is important to determine whether they were fashioned from meteoric iron or from manufactured iron, the difference in cultural level represented by the use of the one kind as contrasted to the other being very great.

The problem of making a correct identification of ancient materials found in excavations may be very different from the problem of identifying the same materials in a fresh condition. Thus, for example, a clean piece of copper may be differentiated from a clean piece of bronze at a glance because of the difference in color, but no such difference is apparent when the two materials are in a highly oxidized condition, as they usually are when found in excavations. Furthermore, in the identification of materials found in excavations it is not so important to determine what a material is now, as it is to determine what it was originally before it underwent a series of chemical changes. During the excavations at the site of the ancient Agora in Athens, Greece, an object was found in the form of a thin shield. This was described as a bronze shield before a chemical examination was made. Actually no free metal of any kind could be found in it and no compounds of tin could be found among the copper corrosion products. The conclusion was that it was originally a shield of beaten copper. Though the original nature of inorganic materials may usually be determined with little difficulty, it is otherwise with organic materials for these are not only more likely to undergo extensive chemical changes but such changes are generally much more complicated.

For materials that are deceptively similar to each other in appearance chemical tests are of course a necessity for the purpose of differentiation. Silver containing a moderate proportion of alloy cannot with certainty be distinguished from fine silver on the basis of appearance, though such a distinction may be very significant when the objects are in the form of coins. Still more necessary is identification by chemical tests for those materials the appearance of which gives little or no clue as to their actual nature. For example, a white material in the form of lumps and fine powder was found in ornamental ceramic containers in graves of Greek women buried about the fourth century B. C. in Attica. Also found were various other articles of the toilet. After some speculation as to whether the white material was chalk or white clay, chemical analysis showed that it was artificial basic lead carbonate or white lead, evidently used as cosmetic powder.

It is important to note that the exact chemical identification of ancient materials may lead to various inferences and interpretations that are fully as important, or even more important, than the mere establishment of identity for the purpose of correct description. Thus the preceding example of the identification of a material as white lead immediately implies the discovery and use of a process for its manufacture, its sale as an article of commerce, and the employment of a poisonous substance as a cosmetic that may well have had an adverse effect on the public health.

INDICATIONS AS TO SOURCES OF MATERIALS, THE EXISTENCE OF COMMERCE IN PARTICULAR MATERIALS, AND THE DIRECTION OF TRADE ROUTES

The presence of numerous specimens of a material of foreign origin at an archaeological site is a clear indication of the import of such a material through trade or commerce. If the source of this material can also be located then the

direction or path of this trade or commerce can be established also. Sometimes the chemical examination of materials can determine whether they are of foreign origin or can supplement other evidence indicating a foreign origin.

Deposits of native copper do not occur in Ohio, yet a large number of artifacts of native copper have been found at various sites in the state. The only possible explanation is that native copper must have been brought into the state, either by trade or in this particular case by expeditions to the source. That the deposits of the Lake Superior region were the source of this copper receives additional confirmation from the fact that the chemical composition of the copper of the artifacts is the same as that of the copper of the Lake Superior deposits.

At the Agora excavations in Athens a number of specimens of a bright red pigment were found which on analysis turned out to be cinnabar, the native sulfide of mercury. The character of the geological formations in Greece do not indicate that cinnabar ever occurred there in appreciable quantities, and therefore it was concluded that in all probability this was an imported pigment. The discovery of ancient cinnabar workings is Asia Minor supports this conclusion and in addition indicates the probable existence of an export trade in cinnabar from Asia Minor to Athens.

True Baltic amber is rather easily differentiated from other fossil resins because it yields a considerable proportion of succinic acid on dry distillation. Objects of fossil resin, identified by this characteristic as Baltic amber, have been found in considerable numbers at prehistoric sites in Greece. In spite of the considerable distance involved, either by the sea route or by travel across the then undeveloped land areas of Europe, the conclusion is that a commerce in amber must have existed between the Baltic coast and the Mediterranean region even in these remote prehistoric times. Indication of the existence of a trade in the reverse direction, at least at a much later period, is given by the composition of small brass objects dating from the opening centuries of the Christian Era which have been found in the eastern Baltic coastal region. There is no evidence that such brass was of native manufacture, and indeed it is improbable that it was in view of the cultural state of the inhabitants of the region at that period. The significant fact is that the brass of these objects was found to have the same composition as the brass of the Roman coins of the same period. From this it has been reasonably concluded that Roman coins reached this distant region by trade and were converted into these objects by the inhabitants.

EXPLANATION OF UNUSUAL PHENOMENA ENCOUNTERED IN THE COURSE OF EXCAVATION

Slow chemical changes extending over long periods of time not infrequently result in unusual phenomena which may lead to erroneous conclusions if not interpreted correctly. For example, an ancient weight found during the excavation of the Agora in Athens appeared to consist of bronze or copper, but a chemical examination showed that it was actually a lead weight coated superficially with a thin plating of metallic copper and with corrosion products of copper. The lead itself was of the usual high degree of purity. From a consideration of the facts it seemed most likely that the thin plating of copper was formed by electrolytic displacement when copper bearing solutions came into contact with the lead object, and that the copper corrosion products were formed by the subsequent corrosion of part of the electrolytically deposited copper. The copper bearing solutions were probably produced through contact of ground water with neighboring bronze or copper objects. In view of the fact that the layer of copper and copper corrosion products on the lead object was still very superficial in spite of burial for approximately 2000 years, it is very probable that the copper bearing solutions were extremely dilute and that as a result the rate of the plating process was exceedingly slow. Similarly, what appear to be bronze or copper examples of well known ancient

silver coins have been found which on examination have proved to be actually such silver coins superficially coated with metallic copper and its corrosion products. This type of plating apparently occurred because such coins were simultaneously in contact with copper bearing solutions and an active metal.

Sometimes well-crystallized minerals are found in association with ancient objects, and it may wrongly be concluded that these minerals were originally associated with the objects. The presence of such minerals is more often the result of their formation by natural means near, on, or even in ancient objects after their burial. However, the objects themselves often play a necessary part in the formation of the minerals. For example, the formation of cuprite or azurite on or near bronze objects depends primarily of the material of these objects. Occasionally the association of certain substances with objects occurs because of some very unusual or special condition. For example, a dark brown compound was found in the layers of corrosion products on lead objects from one part of the Agora excavation area. This brown compound was identified as lead dioxide. In view of the fact that this area was adjacent to, and in part actually included, a section of the road bed of an electric railway line it seemed probable that stray electric currents were the essential agency in the formation of the lead dioxide on the lead objects.

DETERMINATION OF THE USES OF OBJECTS

Though the uses to which ancient objects were put is often a matter readily decided by simple inspection, a chemical examination may sometimes be helpful in establishing the exact use to which a given object or a given kind of object was put. This is especially true for containers of various sorts. For example, in the excavations at the Athenian Agora numerous fragments of empty jars were found on the interior surfaces of which was a black or dark brown resinous coating. Since the unglazed pottery body of such jars was porous it was evident that the purpose of the internal resinous coating was to render them impervious to liquid. Impressed stamps on the handles of the jars showed that they were of foreign origin, and it therefore was further evident that they were containers in which some liquid product was imported. Obviously they were not, originally at least, containers used for water. Experiments on the solubility of the resinous coating in various liquids showed that it was more or less readily soluble in vegetable oils. Hence the vessels could not have been used as containers for olive oil or any other vegetable oil. Though soluble to some extent in concentrated alcoholic solutions, the resinous coating was not appreciably soluble in dilute alcoholic solutions containing less then 20% by volume. Therefore it appeared very likely that these jars were containers in which wine was imported. The resinous coating was found to consist of fused mastic resin.

As another example may be cited the results of an examination of the contents of a small jar found in the excavations at Corinth. This was a small round jar of green-glazed pottery with a very narrow neck. It was of Byzantine manufacture and probably of the 12th century A. D. Such vessels have long been classified as pomade jars, but no concrete evidence as to what they originally contained had ever been produced. When found this particular jar appeared to be intact since it was obviously full of something, and its neck was tightly sealed with what appeared to be a corroded iron stopper. However, on opening the vessel it was seen that the rusted mass which filled the neck was simply a part of the remains of an original iron applicator rod that had stood in the vessel and had fitted loosely in the neck. This rod had expanded on rusting and consequently had filled the opening. The vessel itself was found to be filled with fine clay which evidently had infiltrated into the empty or nearly empty jar before the neck had become sealed through rusting and expansion of the iron rod. The hope of finding the jar full of its original contents or the modified remains of these contents therefore met with disappointment. However, the clay from the vessel was extracted with boiling ether and on evapora-

tion of the ether extract there was obtained a considerable quantity of a fatty material that was evidently the remains of the original material left in the vessel before it became filled with clay. This fatty matter was found to consist largely of a mixture of fatty acids which from their properties were judged to be the result of the hydrolysis of the glycerides of a vegetable oil or a mixture of vegetable oils. Evidence obtained by chemical means therefore gave a firm basis to the previous opinion that vessels of this type were used as containers for oils or oily preparations such as might be used for dressing the hair.

DETERMINATION OF THE DETAILS OF ANCIENT TECHNICAL PROCESSES

The scientific examination of ancient objects can yield information about the technique of their manufacture that cannot otherwise be obtained. For example, the microscopic examination of metal objects, coins for example, by the methods of metallography can show whether they were produced by casting or by striking, or by a combination of casting and striking. Likewise the examination of weapons yields interesting details on the method of manufacture. It has been observed, for example, that the edges of bronze or copper weapons were often subjected to severe cold work such as might have been done by long continued hammering, whereas the body of the weapons largely retained their original cast structure. Evidently the hardening effect of cold working was well recognized and deliberately utilized.

Sometimes modern experiments in imitation of ancient processes yield information on the details of the procedures that must have been employed in order to achieve the results now seen in ancient objects. On ceramic bodies and glazes a considerable number of such experiments have been made. It has been found, for example, that the black glaze on certain types of ancient pottery could only have been produced by firing in a reducing atmosphere.

DETERMINATION OF CHRONOLOGICAL SEQUENCES

Chemical methods of investigation are apparently not of general use for the determination of the chronological sequences of ancient objects, though for certain special kinds of objects they may be of considerable use, at least in connection with other kinds of evidence. For example, it was found as a result of quantitative chemical analyses of a large number of ancient Greek bronze coins from different localities that there exists a broad general relationship between the date of production of such coins and their chemical composition. Coins of the earliest date generally contain the highest proportion of tin and very little or no lead. Somewhat later coins contain a lower proportion of tin and a moderate proporation of lead. The latest coins contain the lowest proportion of tin and a very high proportion of lead. Furthermore, a rather sharp change in the composition of these coins was observed to have taken place shortly after the middle of the second century B. C. which may be ascribed to the fall of Carthage and the consequent stoppage in the shipment of tin by the sea route from Britain. This relationship between the chemical composition of the coinage alloy and its date of production has been successfully applied, in connection with other evidence, to the arrangement in chronological sequence of a considerable number of types of the late bronze coins of Athens.

Chemical methods of investigation are sometimes useful for fixing the earliest possible date at which a given object could have been manufactured. For example, it appears to be definitely established on the basis of analyses of numerous dated objects that zinc was not introduced into alloys produced in Mediterranean countries until after the middle of the first century B. C., and therefore the presence of zinc as an essential component in the metal of an undated object from any of these countries is an almost certain indication that this object was not made before this time.

INDICATIONS OF CULTURAL LEVEL AND ECONOMIC CONDITION

The presence or absence of certain kinds of materials may be an index of the cultural status of a people. Obviously the absence of metal among the remains of a given people indicates a low state of technical development and a low state of general culture. The greater the variety of metals and alloys utilized by a people the greater their technical development, and, as a rule, the higher their general cultural development. The same appears to be true for certain kinds of non-metallic materials such as glazes and glasses. Some materials that serve as indices of this nature may, of course, be recognized without chemical aid, though the application of chemical methods may make their recognition more certain. On the other hand, some kinds of materials that are indicative of cultural level are not easily recognized for what they are without chemical aid. For example, the introduction of lead or tin into glazes, or the introduction of certain of the less common elements into glasses, represent technical advances which may be, and in fact sometimes have been, overlooked in the study of ancient remains. An increase in the variety of materials utilized by a people in the course of their existence may be taken as an indication of a rise in cultural development and conversely a decrease may be taken as an indication of a decline.

It is probable that a rise or fall in the variety of materials utilized is also in general an indication of a corresponding rise or fall on economic status, but a more direct indication of this may be obtained through a chemical study of the particular kind of objects that bear a direct relationship to economic status, namely, the coins of a people. For example, the fineness of Roman silver coins underwent a slow but almost steady decrease that paralleled the increasing economic difficulties that occurred with the decline of the empire until finally nothing but silver-coated coins came into use. Sudden changes in the composition of coins may mark sudden economic difficulties or disaster. As illustrative of this an ancient example seems almost inadequate in view of the many striking examples afforded by the numismatic history of Europe in recent years.

EXPLANATION OF THE ALTERATIONS IN THE APPEARANCE OF ANTIQUITIES AS CONDITIONED BY ENVIRONMENT AND TIME

During long burial in the ground a great variety of chemical reactions occur between the material of most objects and the surrounding soil and ground water. In order fully to explain the appearance of objects found in excavations, to deduce with confidence their probable original appearance, or to decide upon the proper method of restoration, it is often essential to understand the nature and course of these chemical reactions. The appearance and general condition of objects of the same material and of the same age taken from different excavation sites may be very different. Thus a simple tin bronze from one site may be coated with a hard coherent layer of corrosion products of the sort commonly called a patina, whereas a similar bronze of the same age from another site may be coated with loose porous masses of corrosion products. The very extent to which objects of a given material undergo corrosion at one site as compared to those at another site may vary enormously. For example, archaeologists observed that bronze found at Corinth was almost invariably in a severely corroded state, whereas similar bronze of equal or greater age found at certain other sites in Greece was not so corroded. A special investigation into this phenomenon showed that the ground water at Corinth happens to contain an abnormally high concentration of chloride, and that this is sufficient to account for the severe corrosion of the buried bronze.

Chemical considerations may also serve to correct common misconceptions as to the original appearance or nature of certain materials or objects. By reason of its usual beautiful iridescent appearance ancient glass, for example, is regarded by some as a product artistically superior to modern glass, and one that cannot be successfully imitated by modern glass makers. Observation has shown, however,

that ordinary modern soft glass also becomes iridescent when buried in certain soils, especially those slightly alkaline because of the presence of ammonia from decaying organic matter. Experiments have also shown that this action may be greatly hastened by treatment with alkaline solutions at an elevated temperature. All such action consists in the removal of the metallic ingredients from the surface of the glass leaving thin films of silica on the surface which refract light in spectral colors. If ancient iridescent glass has any real artistic superiority over modern glass made iridescent by chemical treatment it is because the ancient glass has been subjected by natural conditions to a very slow and long continued action which has caused a deeper and perhaps somewhat different type of leaching of the surface.

RESTORATION AND PRESERVATION OF ANTIQUITIES

In general, the deterioration of buried objects is predominantly the result of chemical change, and it is therefore reasonable to expect that the restoration of such objects should be best effected by chemical treatment. The deterioration of bronze or copper, for example, is primarily the result of oxidation, and the reverse process of reduction should tend to restore this to its original condition. This principle has been applied extensively to the restoration of bronze and copper objects. In practice this is done by electrolytic procedures, in one of the best of which the corroded object is made the cathode, an inert electrode of nickel or platinum is used, and the electrolyte is a dilute solution of sodium hydroxide. On passage of a feeble current for a long time, often several weeks, the corrosion products on the object are slowly reduced back to metal, much of which plates back on the object in approximately its original position. At the same time any clay or sand entangled in the corrosion products falls to the bottom of the electrolytic bath. When reduction is complete the object is scrubbed to remove nonadherent matter, thoroughly rinsed with distilled water, and dried in an oven. The results achieved by this means are much superior to those obtained by former methods of mechanical cleaning.

Even when objects are of such nature that they undergo no appreciable chemical deterioration during burial, they may become coated with foreign matter that requires chemical treatment for its safe and effective removal. For example, once there was found an important inscribed Sumerian cone of baked clay that was extensively incrusted with a thick and adherent deposit of calcium carbonate and calcium sulfate which could not be removed mechanically without flaking off the softer inscribed surface of the cone. Treatment with hydrochloric acid readily removed the deposit without damaging the cone. Similarly, incrustations of calcium carbonate on pottery are now often removed on a large scale at excavation sites by treatment with hydrochloric acid.

Whether ancient objects are restored by chemical means or not, problems concerning their preservation for purposes of exhibition or study often arise, and these are frequently best solved by the application of chemical principles. In ordinary air the corrosion of an ancient metal object, for example, may continue at an appreciable rate unless proper precautions are taken. For such an object this problem is sometimes best solved by coating it with a protective layer of wax or synthetic resin. Where such treatment is not desirable or feasible the object may be kept in a sealed glass case containing an inert gas, or in a case containing a powerful desiccating agent that keeps the air very dry. Sometimes special problems arise such as the so-called bronze disease, or cylic corrosion, of bronze or copper objects. Such a problem can only be solved by application of chemical principles.

Occasionally certain problems of this sort not directly connected with ancient objects, yet of interest to the archaeologist, may also be solved by chemical means. The preservation of paper impressions of inscriptions on stone is an example. These paper impressions, which are commonly used in the study of lapidary inscriptions, are obtained by applying one or more large sheets of chemical filter paper over the inscription, thoroughly wetting the paper, pressing it into the carved

letters on the stone, letting it dry in place, and then peeling off the dried paper. In this way an exact reverse impression of the inscription is taken. Unfortunately, these convenient copies are fragile and there is a tendency for fine details to be obliterated on frequent handling, or even on storage under humid weather conditions when a number of impressions are piled together. It was found that by spraying such impressions with a special methyl methacrylate lacquer they could be stiffened and toughened to such an extent that these disadvantages connected with their use were completely eliminated.

DETECTION OF FALSE ANTIQUITIES

The forgery or alteration of ancient objects presents a problem that plagues the dealer in antiquities, the museum archaeologist, and sometimes even the field archaeologist. Frequently a counterfeit ancient object may be detected by chemical tests or analyses. As an example may be cited the means by which an alleged ancient Greek bronze statuette, offered for sale to a museum director, was shown to be not as represented. Though satisfactory from the standpoint of style, this object appeared suspicious because of the thinness of the corrosion products or patina on its surface. On analysis of a small sample of the metal taken from an inconspicuous place in the base it was found that this metal lacked the usual impurities such as arsenic, gold, nickel, and silver commonly present in small proportion in genuine ancient bronze. Furthermore, the alloy was found to contain zinc as a major component which failed to agree by at least several centuries with its alleged date. On these bases it was concluded that it very probably was an object of modern manufacture.

Certain physico-chemical methods of examination, either alone or in connection with chemical tests, are useful for detecting forged antiquities and especially for detecting modern additions, alterations, or repairs. Examination under ultraviolet light, for example, is especially useful for the critical examination of ivories and marbles. Under ultraviolet light different marbles fluoresce different colors, and the surface of ancient marble frequently has a characteristic fluorescent color which is very different from that of fresh stone of the same kind. On this basis alterations or repairs in an ancient marble object which are not at all visible in ordinary light may become strikingly conspicuous when the object is viewed under ultraviolet light. Similarly, infrared light and X-rays have been found useful in the detection of falsification.

CONCLUDING REMARKS

The above general categories and the illustrative examples, of which many more could be given, sufficiently show that chemistry may be of important service to archaeology. The titles in the appended bibliography, which is by no means exhaustive, further show the aid that chemistry may render to archaeology. As far as the writer has been able to determine this is the first general bibliography on this special field of investigation. A peculiarity of the published work in this field is its scattered nature and the consequent difficulty of locating and assembling it. Much has been published in obscure periodical works and in the form of pamphlets in small editions. Another considerable proportion has been published in the form of extensive footnotes or appendices in archaeological works. Because of the nature of the subject and the way in which much of it has been published a good many items have escaped the usual scientific abstract journals and general indices. As indicated by the extent of this bibliography much work has already been done in the past. Much more remains to be done, however, and it should be possible eventually to erect a considerable body of special knowledge having its own data, techniques, and general rules. For such a body of special knowledge, a distinct and separate branch of applied chemistry in itself, an appropriate descriptive name would be *archaeological chemistry*.

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FAIRY SHRIMP POPULATIONS OF NORTHEASTERN OHIO IN THE SEASONS OF 1945 AND 1946

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Throughout the late winter and spring of the years 1945 and 1946, field studies on anostracan phyllopods (fairy shrimps) were continued in Portage, Summit, Stark, and Crawford Counties of northeastern Ohio. Reports on this work for the years 1941–1944 inclusive have already been published (Dexter and Sheary, 1943; Dexter, 1943 and 1946). This paper presents the observations on seasonal and geographical distribution of fairy shrimps from a study of more than eighty pools and ponds during the fifth and sixth years of an annual survey, including a week by week life history study in two ponds throughout the entire fairy shrimp season, together with new information on ecological relationships of this group of sporadic crustaceans. Also, there is added a compilation of collecting records of the Anostraca from other sections of Ohio.

Acknowledgment is made to those who have kindly contributed specimens and records to this study. Their names are given in the paper in connection with their specific contributions. We are indebted to Dr. Folke Linder of Uppsala, Sweden, and to Dr. Edwin P. Creaser for service rendered in settling certain taxonomic problems. We thank Dr. Kenneth L. Kelley for making the collections for two weeks from the two ponds in which life history studies were in progress while the senior writer was out of the state.

Review of Field Collections—Season of 1945

In 1945, 83 pools and ponds were visited. Sixty-five of these had been studied and reported upon in previous years. Six new stations were added in Portage County and four new ones in Stark County. Eight stations, which had been established near Bucyrus in Crawford County by the junior author in 1944, were also added to the survey. All pools known to have contained fairy shrimps at any time during the previous four years were studied. Four pools were dry when visited. Twenty-three contained no specimens, but only one of these (C3) was ever known to be populated with Anostraca. Fifty-six stations yielded specimens of *Eubranchipus vernalis* (Verrill). Six of these had not contained fairy shrimps since first investigated in preceding years (two in 1941, two in 1942, and one each in 1943 and 1944). Eight of the new stations contained *E. vernalis*. Six of the eight pools containing this species in Crawford County were known to be populated with the same species when investigation was first made in that county in 1944. Five pools in the other counties (one in Portage, two each in Summit and Stark Counties) which had fairy shrimps at various times in past years, but not in 1944, had them return in 1945. Ten pools had a definite increase in abundance in 1945 over that of 1944 while only six suffered a marked decrease in abundance. The largest specimen of *E. varnalis* collected in this study to date was a female which measured 32 mm. and was collected from pond S4 on April 1, 1945.

In a previous report (Dexter, 1943), *Pristicephalus bundyi* (Forbes) was recorded from Ohio for the first time. In a critical revision of certain groups of Anostraca, Linder (1941) suggested that probably this species should be placed in the genus Chirocephalopsis, a genus which has not formerly been recorded for North America. In conversation with Dr. Linder in the summer of 1946, when he was in this country working on the phyllopod clolections of the United States

National Museum, it was learned that he is quite convinced of the need for such a change. For that reason the present paper will follow such a classification. *Chirocephalopsis bundyi* (Forbes) was not collected in Ohio after the original find in 1942 until the season of 1945 when a single specimen was collected from the original site (C7) on March 24 by Miss LeMoyne Unkefer, a student at Kent

TABLE I

SUMMARY OF FIELD COLLECTIONS OF FAIRY SHRIMPS—SEASONS OF 1945 AND 1946

P=Portage County C=Stark County
S=Summit County Cr=Crawford County

	1945				1946			
	P	S	C	Cr	P	S	C	Cr
Number of pools studied	44	12	19	8	35	13	20	15
Pools dried out at time of visit	4	0	0	0	3	0	2	0
Pools without fairy shrimps	17	3	3	0	21	6	3	0
Pools containing *E. vernalis*	23	9	16	8	11	7	15	15
New records of *E. vernalis* (first appearance known)	P8 P23 P42 P54 P90	0	C17	0	P93	0	C15	0
New stations containing *E. vernalis*	P95 P96	0	C16 C19 C20 C21	Cr7 Cr8	0	S21	C22	Cr9 thru Cr15
Pools from which *E. vernalis* disappeared	0	0	C3	0	P18 P23 P30 P37 P40 P42 P50 P55 P58 P80 P90 P96	S3 S4 S11	C6	0
Return of *E. vernalis*	P37	S3 S4	C10 C18	0	0	0	0	0
Increase in abundance of *E. vernalis*	P17 P18 P30 P55 P91	S2 S5 S12 S14	C14	0	P54	0	C9 C10 C16 C21	Cr4 Cr5
Decrease in abundance of *E. vernalis*	P40 P79	0	C2 C8	Cr4 Cr6	P8 P17 P88 P91	S1 S2 S5 S12	C7 C8 C11 C12 C14 C18	0
C. bundyi found with *E. vernalis*	0	0	C7 C18	0	0	0	0	0
E. holmani found with *E. vernalis*	0	0	C21	0	0	0	0	0

State University, and another specimen collected by the writers on April 8 from a pool (C18) several hundred yards distant from the other. This second pond was known by the junior author to contain *E. vernalis* in the seasons of 1942 and 1943 as well as in 1945, but no fairy shrimps were found there in 1944. Both specimens of *C. bundyi* were found among specimens of *E. vernalis*.

A third species of Anostraca for the State of Ohio was discovered for the first time in 1945. From a small collection of fairy shrimps taken in a shallow pool (C21) on Route 30 between Canton and Massillon on April 25, there was found a

single male specimen of *Eubranchipus holmani* (Ryder). This species, under a variety of names, has been reported previously from the following localities: New Jersey (type locality); Long Island, New York; New Haven, Connecticut; Chincoteague, Virginia; and Tiptonville, Tennessee. The taxonomy of this species has been much disputed (see Creaser, 1930), but our specimen was determined by both Dr. E. P. Creaser and Dr. Folke Linder as species *holmani* as described by Ryder, and it is the opinion of Dr. Linder that it should be assigned to the genus Eubranchipus. While Dr. Creaser at first suggested that it be placed in the genus Branchinella, it seems best to record it as *E. holmani* in view of Linder's forthcoming revision of the North American Phyllopoda.

Table No. 1 gives a summary of the field collections for 1945 and compares the results of that year with 1946. The map on page 33 of a previous report (Dexter, 1946) may be consulted for the location of many of the stations mentioned in this paper. The season of 1945 was the most favorable one encountered in six consecutive years of collecting. Every pool, except one, in which fairy shrimps were ever known to occur in past years contained *E. vernalis* in 1945. It was the only year in which all of the three species known from Ohio were collected.

Review of Field Collections—Season of 1946

During the sixth survey a total of 83 pools and ponds including nine new stations were visited. Five had dried out by the time they were reached. Thirty contained no fairy shrimps, including 16 which were known to have *E. vernalis* the preceding year. Three of these had had this species for five years, two for four years, three for three years, and four each for two years and one year respectively. Forty-eight stations contained *E. vernalis* in 1946. Two of these were inhabited for the first time since being studied over a period of two and three years respectively. All nine of the new stations added to the survey this year contained specimens. One of these (C22), however, yielded but a single specimen. The collections from seven ponds were considerably more abundant than those obtained from the same place the preceding year, while 14 ponds had a much smaller population than in 1945. Less than a dozen specimens were collected from five of these 14 stations. The largest specimen collected in 1946 was a female which measured 33 mm. and was taken from pool Cr4 near Bucyrus. Neither *Chirocephalopsis bundyi* nor *Eubranchipus holmani* was collected in 1946.

It is interesting to note that some other collectors in Ohio experienced a similar failure to find fairy shrimps as often in 1946 as in former years. However, a few also failed to find them in expected places in 1945 when the writers experienced the best year of collecting. Some of those reporting positive records in the past (see Dexter, 1946), but who failed to find specimens in the same places in later seasons are as follows: Miss Rose Azary collected *E. vernalis* on April 3, 1945, from the same pool near Painesville from which records were reported for 1944, but in 1946 she failed to find it there. Another pool in the same pasture, however, contained specimens for the first time in three years. Mr. Alfred Linscheid found *E. vernalis* to be abundant on April 10, 1945, in the Warrensville Heights swamp as in previous years. In 1946 three attempts were made to collect it from the same location, but he could find only two specimens there which were taken on March 28. Dr. William A. Dreyer failed to find fairy shrimps in the three ponds previously reported near Goshen on field trips made on February 25, 1945, February 26 and March 8, 1946. Dr. William C. Stehr found a new locality record for *E. vernalis* in Athens County in 1945 but did not find it in those pools reported for that county in past years. In 1946 he did not find fairy shrimps in any of the pools he examined including one which had been inhabited for many years up until 1943. Mr. Ernest Vickers did not find any fairy shrimps in the pools of Mill Creek Park at Youngstown during the spring of 1945 and 1946.

The sex ratio of *E. vernalis* collected in past years from Portage, Summit and Stark Counties has been reported earlier (Dexter, 1946) to average 1 male: 1.5

females. This ratio was approximately true for all samples taken in Portage and Summit Counties. A sample from some Stark County ponds taken in 1943, however, was found to have a ratio of 1 male: 0.5 female. Another sample of 169 specimens collected from these same ponds, located west of Canton, still showed a predominance of male specimens in 1946 with a ratio of 1 male: 0.8 female During the same season a sample of 386 specimens taken from the ponds in Crawford County had a similar ratio of 1 male: 0.75 female. Apparently the sex ratio is variable from one locality to another, and at times males are more numerous than females.

In 1943 an experiment was attempted to introduce *E. vernalis* into a temporary pool which did not contain this animal. On March 25, 32 male and 68 female specimens of this species collected from pond P7 were transferred to pond P42 which contained no fairy shrimps since the survey began in 1941. One week later two specimens were collected during a cursory re-examination of the pool. That fall the field in which the pool is located was plowed and planted with winter wheat after lying fallow for several years. Water collected in the field as usual during the following spring, but fairy shrimps could not be found after a thorough sampling on two different occasions. In the spring of 1945, however, one male and one female specimen were collected there. The next year no specimens could be found. The cultivation of the field may have prevented the successful introduction of fairy shrimps. Where they have become well established, however cultivation does not seem to interfere with them. Two of the most productive pools in Crawford County (Cr5 and Cr8) are in cultivated fields.

Comparison of the Life History of Eubranchipus vernalis in Two Ponds

Pond P7 filled with rain water for the first time in 1945 on February 21. Three days later metanauplii of *E. vernalis* were collected which averaged 1.25 mm. in total length. On March 10 only a single specimen was found in the plankton samples. This measured 5.5 mm. whereas on this date during the preceding year the shrimps were only four days old and measured 2.5 mm. Subsequent collections in 1945 yielded abundant specimens until April 7 when the last collection for the season was made from this pool. After that date the water disappeared rapidly. Warmer water in 1945 than in the previous year resulted in a more rapid rate of growth, earlier maturity, and uniformity of size for adult specimens over a period of three weeks. Collections of 1944 were made until April 22, although the length of the season for fairy shrimps was the same each year, being a little more than six weeks. While the pond refilled on May 17, 1945, no second hatching of fairy shrimps was found to have taken place as occurred in May of 1943.

In 1946 pond P7 filled from melted ice in the second week of January. The first collection of *E. vernalis* was made on January 12 and averaged 2.5 mm. in length. This early hatch was destroyed in about two weeks, however, when the pool froze to the bottom and remained frozen solid for three weeks. Ferguson (1939) reported that *E. vernalis* is not found in pools in the Ontario region with a depth less than two and one-half feet because they would be frozen to the bottom during severe winters. In the Ohio region this does not hold true as we shall see. On February 14 rain melted the ice and refilled the pond. By the end of three days, *E. vernalis* had hatched again and measured 1.25 mm. On February 23 they were about the size of those collected on February 24, 1945. The water in the early season of 1946, however, was cooler, resulting in a slower rate of growth and a smaller maximum size attained by the time the pool dried out. The season of this second hatch, the only one which reached maturity, was again a little over six weeks in duration. Table No. II summarizes the life history of this fairy shrimp in pond P7 for the two years.

Pond P88 in the same pasture with pond P7 near Brimfield, also filled with rain-water on February 21, 1945. While the first specimens, collected on Feb-

TABLE II

COMPARISON OF LIFE HISTORY OF *Eubranchipus vernalis* IN POND P7 IN 1945 AND 1946

1945						1946					
Date	°C	pH	Length in MM	Growth in MM	Notes	Date	°C	pH	Length in MM	Growth in MM	Notes
						1-5	1.0	5.9	.....	.....	Pond ½ full with coat of ¾ in. soft ice, 6–8 in. water. No fairy shrimp.
						1-12	4.4	5.4	2.5	.....	Pond ½ full. *E. vernalis* found—first record in 1946.
						1-19	0.5	5.5	3.5	1.0	3 inches ice over pond; 3–4 in. water under ice.
						1-26	.....	.....	.....	.....	Pond frozen to bottom. Ice 4–5 inches.
						2-2	.....	.....	.....	.....	Pond frozen to bottom. Ice 4–5 inches.
						2-9	3.0	5.3	.....	.....	Patches of ice slowly melting; few puddles under ice, in. or 2 deep. No fairy shrimps found.
						2-17	1.6	5.3	1.25	.....	Pond refilled on 2-14 from rain and snow. Froze over early a. m. of 2-17. *E. vernalis* hatched out for 2nd time. Collected under 1 in. of soft ice.
2-24	2.8	5.9	1.25	.....	Rain filled pond on 2-21. 1st collection in 1945. Plankton sample taken under ice.	2-23	0.5	5.5	1.75	0.5	Collected under 2 in. of soft ice.
3-3	6.8	6.0	.....	.....	None found in plankton sample. Pond overflowing.	3-2	4.0	5.9	1.50	.....	Pond flooded over. One specimen of *E. vernalis* only. Flood waters may have scattered fairy shrimps. Ice practically gone.
3-10	5.0	6.1	5.50	4.25	One specimen only collected in 2 plankton samples.	3-10	2.2	6.0	5.4	3.9	Pond fully covered with ⅜ in. of ice. Froze over 3-9 after a wk. of warm weather (50–60° F.). Many pink *E. vernalis* specimens collected. Few metanauplii also collected.
3-17	19.0	6.4	11.53	6.03	Specimens fairly numerous. Pond ½ dried up.	3-15	11.7	5.9	8.7	3.3	Pond full. Orange-pink in color. Immature.
3-26	18.3	6.7	17.55	6.02	*E. vernalis* abundant. Water level same as for 3-17. Egg sacs developed.	3-23	16.0	5.7	15.9	7.2	Pond ½ full. Eggs developed.
3-31	11.7	6.3	17.45	.....	Normal coloration for adults. Water level approximately the same.	3-29	19.5	6.5	16.3	0.4	Pond reduced to scattered puddles. Last record of *E. vernalis* in pond P7 for 1946.
4-7	15.3	6.2	17.98	0.53	Pond about two-thirds dried up.	4-5	.....	.....	.....	.....	Pond dry.
4-14	.....	.....	.....	.....	Pond nearly dried up. Scattered, shallow puddles only. No fairy shrimps.						
4-22	.....	.....	.....	.....	Pond completely dried up.						
5-26	17.2	6.2	.....	.....	Pond refilled on 5-17. 5–6 in. of water in places. No fairy shrimps.						

ruary 24, averaged the same size as those in pond P7, it seems that this initial hatching did not survive. A week later the specimens in pond P88 were no larger than those first collected indicating a second hatch had taken place. Unfortunately, none was found in the plankton samples taken from pond P7 that same day which could be used for comparison. However, on March 10 the shrimps in pond P88 were only 1.7 mm. in size as compared to a length of 5.5 mm. in pond P7. During the succeeding weeks, specimens in this pond (P88) were consistently smaller, grew less rapidly, and attained a somewhat smaller maximum size than in pond P7. They did, however, persist in the deeper pond for two weeks longer than in P7, and on the date of the last collection from that pond, the presence of immature individuals in P88 indicated that hatching had taken place there over a longer period of time. Somewhat cooler water on the average and the greater volume of water in P88 may explain in part these differences. On April 22, 1945, the last weekly collection of fairy shrimps for the season was made in pond P88. On the same date one year previous, the first collection of the season for this pond was made since it did not fill that year until April 11 and contained *E. vernalis* until May 13. Water remained in the pond in 1945 for many weeks after April 22 and the temperature did not go above the toleration limit, but the fairy shrimps disappeared soon after reaching maturity that year in this pond.

On January 12, 1946, metanauplii of 2.0 mm. size were collected. None had been found in the water under the ice a week earlier. They lived for a little more than three weeks, most of the time under ice, increased in size to 4.0 mm., and then disappeared. In this case it was not because of freezing to the bottom as it was in pond P7. Rather, the water below the ice turned yellow in color and became filled with gases of puterfaction. After thawing from warm rain on February 14 and filling several inches deeper, the pond refroze. Fairy shrimps were not found again until February 23 when a single specimen measuring 5.0 mm. was collected. Without much question this was a survival from the original hatch and was the last one seen from that group. One week later another specimen, the only one taken in several plankton samples, measured 1.2 mm., indicating a new hatch of shrimps had taken place after the polluted water had cleared. Those hatching at this time were not numerous, however, since subsequent samples were always small. Also, it appears that the second hatching took place over a period of days since the average size of the sample dropped abruptly on two occasions as the earlier hatched shrimps matured, died off, and left the immature and smaller ones still living in the pond. A similar situation was found in a population of *E. serratus* in a pond in east central Illinois (Dexter and Ferguson, 1943). Having hatched later, and living in a deeper pond which did not dry out until summer, the fairy shrimp population of pond P88 persisted for three weeks longer than that in pond P7. This second population of *E. vernalis* in station P88 paralleled very closely the life history of this species in the same pond the year previous. Table III presents the data of environmental conditions and life history of *E. vernalis* in this pond for the years 1945 and 1946.

TABLE III

COMPARISON OF LIFE HISTORY OF *Eubranchipus vernalis* IN POND P88 IN 1945 AND 1946

1945						1946					
Date	°C	pH	Length in MM	Growth in MM	Notes	Date	°C	pH	Length in MM	Growth in MM	Notes
						1–5	1.0	5.3	.....	.....	About 5 in. of soft ice, melting around edges of pond. Free water at margin of pond. No fairy shrimps.
						1–12	4.0	5.4	2.0	.....	Pond ½ full. First record of *E. vernalis* in 1946.

TABLE III—*Continued*

Date	°C	pH	Length in MM	Growth in MM	Notes	Date	°C	pH	Length in MM	Growth in MM	Notes
						1–19	2.2	5.6	3.0	1.0	2 in. of ice over pond. About 15 in. of water below ice.
						1–26	0.0	5.3	3.5	0.5	4 in. ice. About 14 in. of water below ice.
						2–2	0.3	6.1	4.0	0.5	6 in. of ice. About 10 in. water below ice.
						2–9	1.4	5.7	.....	.....	4 in. of ice. About 12 in. water below ice. Water yellowish and has odor of decay. No fairy shrimps found.
						2–17	1.6	5.8	.....	.....	Pond thawed with warm rain on 2–14. Filled several in. deeper from rain and snow. Refroze early a.m. of 2–17 with about 1 in. of ice. No phyllopods found.
2–24	5.0	5.2 or less	1.25	.....	Rain partly filled pond (depth of 5 in.) on 2–21. Plankton sample taken under ice for most part.	2–23	1.0	5.7	5.0	.....	One specimen of *E. vernalis* collected under 2 in. of soft ice. Survival from original hatching.
3–3	6.9	5.2 or less	1.25	0	Depth has increased to 8–10 in. Pond about ¼ full. Many of the larvae have probably hatched since the previous collection.	3–2	5.0	5.7	1.2	.....	One specimen only of *E. vernalis* collected. Pond about ¾ full; ice mostly gone. recent hatching probably.
3–10	4.0	5.4	1.70	0.45	pond slightly deeper.	3–10	2.7	5.7	8.5	7.3	One specimen only collected under ⅜ in. of ice. Pond full. Froze over on 3–9 after a week of warm weather (50–60° F.). No metanauplii found.
3–17	17.5	6.1	3.72	2.02	Pond deeper (2 ft. deep).	3–15	12.2	5.5	13.9	5.4	Pond full. Specimens uncommon. Eggs developed.
3–26	15.3	6.7	13.70	9.98	*E. vernalis* abundant. Egg sacs developing.	3–23	9.0	5.5	10.5	.....	Pond ¾ full. Immature.
3–31	12.8	6.0	15.25	1.55	Egg sacs developed. Color normal for adults. Pond full (about 4 ft. deep).	3–29	20.0	5.9	11.1	0.6	Pond ⅔ full. Small population.
4–7	12.8	5.9	16.03	0.78	Water level nearly the same. Some small, immature individuals indicate a late-hatching group.	4–5	12.0	5.7	11.3	0.2	Pond ⅔ full. Eggs developed.
4–14	14.0	5.9	16.60	0.57	Water level beginning to drop. *E. vernalis* present but not numerous. Medium and adult sized individuals collected.	4–12	15.0	6.2	7.5	.....	Pond ⅓ full. Two specimens only collected. Immature.
4–22	10.0	6.2	13.00	.....	Pond about ¾ full. Only two specimens of *E. vernalis* collected.	4–20	16.0	6.1	13.25	5.75	Pond ⅓ full. Two specimens collected. One was being eaten by a Dytisid larva. Other was mature. Last collection of season.
4–28	12.0	5.9	.....	.....	Pond about ¾ full. No fairy shrimps.	4–27	.....	.....	.....	.....	Pond ¼ full. No fairy shrimps.
5–26	17.0	6.4	.....	.....	Pond about full. No fairy shrimps.						

Observations of Fairy Shrimps in Polluted Water

On a number of occasions relationships have been observed between fairy shrimps and their occurrence in polluted water. *E. vernalis* was found to be numerous in pond C10 west of Canton in 1942. Later that year a quantity of yellow clay was placed in the pond to fill in a portion of it. The following spring the water was heavily silted with the clay much of which remained in a colloidal suspension. Only a single specimen of fairy shrimp could be collected from this water after several attempts were made. In 1944 none could be found. The next year, with turbidity somewhat less, two were collected. By 1946 the clay had settled to such an extent that the water was somewhat clear again. That year the fairy shrimps returned in good numbers in that portion of the pond farthest from the deposit of silt where turbidity was at a minimum. In station C11, an extensive swamp-pond, voluminous inwash of heavily silted water from eroding clay banks may have been responsible for the scarcity of *E. vernalis* there in 1946. It is a common observation that when sediment is stirred up from the bottom of a pond containing fairy shrimps, they swim away from the cloud of silt. Sometimes great quantities of them will be seen swimming away at the very edge of the advancing cloud of silt. Advantage is taken of this fact in collecting them from ponds which have a bottom of fine sediments. It may be that a high concentration of silt interfers with the branchial respiration of phyllopod Crustacea.

As mentioned in an earlier section of this paper, *E. vernalis* which hatched in early January of 1946 in pond P88 lived under ice for at least three weeks. By the fourth week the water under the ice had turned yellowish and possessed a very strong odor of putrefaction. At this time the fairy shrimps disappeared before reaching a size over four millimeters. After the melting of the ice and the addition of rain-water over a period of several weeks, the fouling condition of the pond was cleared up. A new hatch of *E. vernalis* took place on or about March 2. These lived to maturity. In another case, station Cr10 was found to have abundant fairy shrimps on April 6, 1946, even though the water was yellowish and malodorous with putrefaction. Two weeks later, however, no specimens were living in this pool while they were still common in pond Cr11 nearby which showed no signs of putrefaction. Gases of putrefaction confined by a covering of ice seem to be most detrimental to the maturing stages of the shrimp. Mr. Donald S. Lacroix, of the Amherst (Mass.) High School, made a similar observation the same year. He collected numerous immature specimens of *E. vernalis* from under the ice of a pond at Cushman, Massachusetts, from December 22, 1945, until February 16, 1946. The ice was melted off by March 10, and on the 17th of the month only two immature specimens could be collected. After that date no specimens were seen, and apparently they did not reach maturity. Once the pond had lost its ice, the water was discovered to have a "strong odor of sulphur from decaying vegetation." The species was still living on April 17 in another pond a few miles away which had not suffered from putrefaction. In one of the bog ponds of the present study, C15, *E. vernalis* has never been collected in the central portion of the bog. There the growth of vegetation is rank and the surface is ice covered at the season when fairy shrimps are undergoing development. At the edge of the bog, however, where shallow scattered pools occur which lose their ice early and hence do not accumulate gases or lose all of the oxygen content, *E. vernalis* has been collected in small numbers.

While *E. vernalis* seems to be sensitive to suspended silt and to gases and depletion of oxygen through putrefaction, it is known that it can live in ponds polluted with an oil slick. Pond C21 in a rubbish dump located on Route 30 between Canton and Massillon, was covered with an oil slick during the spring of 1946, yet abundant specimens of *E. vernalis* were collected there on April 9 and 17. On the latter date the volume of the water was reduced to a tub full, but the

fairy shrimps were still abundant. It was in this one and another rubbish-filled pond (C19) that *E. vernalis* persisted the longest in the Stark County stations in the seasons of 1945 and 1946. Mr. Frederick R. Burrill of the Peabody Museum at Salem, Massachusetts, sent us some *E. vernalis* that were similarly collected on April 25 and May 9, 1946, from a dump pool which acquires each year considerable rust and oil from refuse thrown into it.

The most remarkable case of toleration of fairy shrimps to adverse physical conditions which has come to the attention of the writers is one involving the brine shrimp *Artemia salina* (L.). A sample was collected by Dr. Seville Flowers of the University of Utah from Great Salt Lake on January 16, 1945. Having lost the address to which they were to be sent, he kept the shrimps in culture in his laboratory until the following year. They were then forwarded to Kent, Ohio, in February, arriving on the 13th of the month. The specimens were shipped in a sealed glass coffee jar partly filled with salt water. Upon arrival the water was lukewarm in temperature—considerably above room temperature—completely clouded with a fine black suspension of silt, and was foul smelling with gases of decay. Mathias (1937) reported that this species will perish in temperatures over 40 degrees C. At first it did not appear that any of the brine shrimps survived, but several days later, after settlement of some of the suspended material, four specimens were found still alive. These were placed in a liter beaker where they reproduced through many generations and maintained a population of about eight to ten individuals. Fresh water species are not so hardy. They will often perish over night in such small containers as a coffee jar even though they are kept in cool, clear pond water. On one occasion the culture of *Artemia salina* was neglected so that the water was allowed to evaporate to a point where large masses of salt crystallized out on the bottom. The shrimps continued to live in the concentrated salt solution for some time. Water was later added and the culture is still living and thriving nearly three years after its collection.

Comparison of Ohio Fairy Shrimps with Those from Indiana, Michigan, and Illinois

Mr. Paul Donaldson, a student at Kent State University, discovered on April 13, 1946, a single pasture pool at Middlefield inhabited with an abundance of *Chirocephalopsis bundyi*. This was the first record of a large population of this species in the State of Ohio, and the first state record of its occurrence as the only species of anostracan phyllopod in a pool. The previous records were based upon a few individuals found mixed with large numbers of *E. vernalis* from the Canton ponds as discussed above. In the spring of 1945, Dr. Frank E. Eggleton of the University of Michigan sent some large samples of fairy shrimps collected that year near Ann Arbor. All of them were *C. bundyi*. The following spring Dr. J. Arthur Herrick, also at the University of Michigan at the time, collected fairy shrimps from many localities in the Ann Arbor region. Eight of his collections contained many specimens of this same species with a few of *E. vernalis* mixed with them. Since the collections from Ohio and Michigan were the opposite in composition, all published records and records known to the writers on distribution of the common species of fairy shrimps in the north central states were compiled for comparison. Our present knowledge of the occurrence of the three common species in that area indicates that this region includes the extremities of distribution of all three. *E. vernalis* is abundant in Ohio, much less common in Michigan and Indiana, and rare in Illinois. *C. bundyi* is rare in Ohio and Indiana, not found in Illinois, but abundant in Michigan. *E. serratus* is abundant in Illinois, rare in Indiana and not found in either Ohio or Michigan.

Additional Records of Anostracan Phyllopods Collected in Ohio

Since the publication of all known records of fairy shrimps from Ohio in the preceding reports of this survey, a number of new localities including records from five new counties have come to the attention of the writers. See Table IV.

TABLE IV

New Records of Anostracan Phyllopods Collected in Ohio

I. NEW COUNTY RECORDS

County	Collector	Location	Species	Notes
Geauga	Paul Donaldson	Middlefield	*C. bundyi*	Collected in abundance 4–13–46 from a single pasture pool. Not found in similar pools nearby.
Ashland	C. H. Kuehnle, Lincoln High School, Canton	Miflin	*E. vernalis*	Four specimens collected in a shallow field pond 3 miles east of Miflin on 4–19–46.
Hardin	Carl Vernard, Ohio State University	Mt. Victory	*E. vernalis*	Common in a woodland pool on 3–17–45, 1½ miles northeast of Mt. Victory.
	R. A. Dobbins, Ohio Northern Univ.	Ada	*E. vernalis*	Occur commonly each year in a small pond 3½ miles northeast of Ada, and in a swamp pond ¾ of a mile southwest of Ada. Collections from both made 3–25–45 and 4–8–45.
Preble		Jackson Township	*E. vernalis*	Collected in April of 1944 by a student at Miami University. Reported by Dr. N. T. Mattox.
Washington	H. R. Eggleston, Marietta College	Marietta	Unknown	Specimens collected for many years in a swamp between Green and Seventh Streets in Marietta, and in a temporary pool at Squaw Hollow, 3 miles west of city.

II. NEW RECORDS FROM COUNTIES PREVIOUSLY REPORTED

Mahoning	Shirley Williams	Canfield	*E. vernalis*	Abundant on 3–24, 25–45 in 2 small pools and one swamp pond.
Cuyahoga	Charles O. Masters	Cleveland	*E. vernalis*	Collected in abundance every year between 1932–41 in a hog wallow on East Forty-ninth Street near Canal Road.
Wayne	R. V. Bangham, College of Wooster	Wooster	*E. vernalis*	Collected from a pool on farm of Prof. James Anderson 4–20–46, 2 miles west of Wooster. Previous record from here reported as species unknown.
		Rittman	*E. vernalis*	Collected by school boys 4–15–46 from a temporary pool northeast of Rittman.
Marion	Carl Venard	Marion	*E. vernalis*	Collected 3–17–45 from several pools 1 mile southwest of Marion in a pasture. Not numerous. First determined specimens from this county.
Mercer	Clarence F. Clark, Ohio Div. of Conser. and Nat. Resources	Granville Township	*E. vernalis*	Collected 4–2–42 from a temporary pool, and from a woodland pool in section 19 on 3–18–45.
Auglaize	Clarence F. Clark	Jackson Township	*E. vernalis*	Collected 4–3–46 from a woodland pool in section 7.
Delaware	W. F. Hahnert, Ohio Wesleyan Univ.	Delaware	*E. vernalis*	Small collection made 3–20–46 from overflow pond of Olentangy River.
		Kilbourne	*E. vernalis*	Large collection made by a student 3–24–46 from a field pond northeast of Kilbourne.
Athens	William C. Stehr, Ohio University	Chauncey	*E. vernalis*	Small numbers collected from a temporary pool along U. S. route 33, northeast of Chauncey, on 4–4–45.

Collecting records have now been reported from 28 counties exclusive of the four studied in some detail in this survey. Thus, 32 of the 88 counties are known to contain definite locality records of fairy shrimps. Nine new localities for previously reported counties are also listed in the table. All of those with known

determination of species are for *Eubranchipus vernalis* except the one from Geauga County which is for *Chirocephalopsis bundyi*. This species, which has also been collected in small numbers mixed with *E. vernalis* populations, and a single specimen of *E. holmani* collected with *E. vernalis* as discussed earlier in this paper, brings the state list of species to three. Determinations of the species were made by Dr. Folke Linder, Dr. E. P. Creaser, Dr. N. T. Mattox, Dr. William C. Stehr, and the senior writer.

Summary

1. Field studies on the occurrence and distribution of fairy shrimps in Portage, Summit, Stark, and Crawford Counties in northeastern Ohio were continued in the winter and spring seasons of 1945 and 1946.

2. Crawford County was added to the annual survey area after preliminary collecting there in 1944.

3. The populations of 1945 and 1946 are compared regarding new appearances, reappearances, disappearances, and fluctuations of abundance from year to year.

4. The season of 1945 was the most successful season during the six years of the survey. Only one pool of those known to be inhabited in former years failed to contain *E. vernalis* in 1945.

5. Three species of anostracan phyllopods were collected in 1945, namely: *Eubranchipus vernalis*, *Chirocephalopsis bundyi* (formerly known as *Pristicephalus bundyi* and *E. bundyi*) and *E. holmani*. The last named is reported from Ohio for the first time.

6. Only one species, *E. vernalis*, was found in 1946 in the regular survey ponds, and this species was not as commonly found as in the preceding year.

7. The life history of *E. vernalis* in two ponds is tabulated in detail for 1945 and 1946. Comparisons are made between them each year and between their populations of 1945 and those of 1944.

8. The sex ratio of *E. vernalis* from the new ponds in Crawford County was 1 male: 0.75 female, similar to the ratio in ponds near Canton in Stark County, but unlike the 1: 1.5 ratio usually found in Portage and Summit Counties.

9. *C. bundyi* was found in abundance, and was the only fairy shrimp present, in a pool in Geauga County in the spring of 1946. This was the first such record for the state.

10. *E. vernalis* was eliminated from ponds in which colloidal clay and excessive gases of putrefaction were present. Oil slicks, on the other hand, did not interfere with populations of this species in several cases observed.

11. The three common species of fairy shrimps in Ohio, Michigan, Indiana, and Illinois are compared in regard to their distribution and relative abundance.

12. Five new county records of Anostraca and additional records in eight other counties are recorded for the State of Ohio. Thirty-two of the 88 counties in the state have now been reported with positive records of fairy shrimps.

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MYRMECOLOGICAL TECHNIQUE

II. IN COLLECTING ANTS, THE USE OF THE COLEOPTERIST, THE HEMIPTERIST AND THE ECONOMIC ENTOMOLOGIST WITH HIS LIGHT OR BAIT TRAP.[1]

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The writer has been much impressed with the quality of ants as regards new and rare species brought to him by friends who collect ants in unusual ways. The average collector of ants looks down on the ground. In many groups such as the *Formica rufa* group and the *sanguinea* group rare species will nest in the same area as that occupied by very abundant species but a collector cannot afford to sample all nests so too frequently he misses the occasional nest of a rare species which is sandwiched in with abundant nests of some similar-appearing common species. Unfortunately for the ground-examining collector, the ants least often captured are those which range over the foliage of trees and large bushes—a regularly neglected collecting area. The arboreal stratum is above the ground and too frequently requires skilled climbing for a thorough examination. Coleopterists and Homopterists find many of their rare things up trees and on bushes and have various means of collecting them—means which are not used commonly by ant collectors.

1. *Coleopterists.*—Common equipment with the Coleopterists is a canvas umbrella which can be opened in an inverted position under a bush or the limbs of a tree and then the bush or the limb jarred with a short club whereupon insects running on the foliage fall into the inverted *umbrella*. *Any ants* will usually be found to be all of one species or a mixture of seldom more than three. These, of course, are arboreal ants which are hunting Homoptera for honey dew. The difficulty with this method of collecting is that the Myrmecologist gets no idea of the nest, its location, or of other castes than the field worker ants. Too frequently the traveling ants are widely dispersed so that the collector gets but a few specimens of a species. We have been particularly impressed with the high quality of bush and tree ants collected in this manner by Professor and Mrs. Josef Knull.

2. *Homopterists.*—Common equipment with the Homopterist is a heavy-bagged beating net, a light weight tightly covered tin can of about one quart capacity which is charged with potassium or sodium cyanide and pill boxes to carry specimens to the lab.

The insects are swept up from bushes, low trees, weeds, grasses, etc. These are shaken into the bottom of the net and the net bag is then stuffed into the cyanide can, or the contents of the net are themselves shaken into the can when the lid is clapped on until death of the catch. Very enthusiastic homopterists may carry two such cans hung at their belt. Such collectors can be heard a long ways off as the cans bang against each other. A lighter net may be used for sweeping herbage.

This method of collecting is of only moderate interest for the ants swept up, as these are mostly ground species which can be collected directly from nests by the myrmecologist where notes on the nest may be collected also. It is not recommended for ants although a myrmecologist can learn much concerning the association of ants with certain species of the honey dew secreting Homoptera.

The Homopterist interested in aphids which are nearly always attended by ants usually collects these very slow moving insects with a pair of tweezers and stores

[1] I. The use of ether in collecting ants. Ohio Jour. Sci. XLVI (1): 10–12. 1946

them in one dram vials of seventy per cent alcohol. Such collectors when interested in the association of aphid and ant bring in enough ants of one species to interest the ant student because the latter has to have a series of worker ants as a minium for identification. Seldom are two or more species of ants associated with one close group of aphids. Ant property rights enter in. For first exploration in a new area such collections have considerable value as most ants can be identified from a fair series of a dozen workers. We have had such series from the inter-mountain area of Utah, Idaho and western Colorado, collected by George Knowlton, Clyde F. Smith and other western students of aphids. Unfortunately the area mentioned is of "island distribution" where an ant species with mountain and valley barriers may show many subspecies which are difficult to determine from workers only. Characters of male, queen and nest are lacking. We do recommend the next:

3. *The Hemipterist with cyanide dust* (*Cyanogas*) *and ground cloth.*—Cyanide dust used in a small hand dusting gun to blow a cloud into bushes and small trees 12-18 feet high brings down as miscellaneous a lot of insects as any collector might desire. With a large sheet or two spread on the ground to catch the dead and the stunned insects the collector has ample time to select specimens of the groups in which he is interested. This is one of the most satisfactory methods of which we know for collecting in the tops of small trees. It is not a rush operation. Few victims attempt to escape and have to be collected in a second stage of the process as is necessary in using a beating net or a club and umbrella. Doctor E. P. Breakey while a student at O. S. U. brought us several species of rare ants taken thus while collecting Hemiptera. He preferred the use of cyanide dust to any other method of collecting.

As ants are in general ground nesting insects the myrmecologist hesitates to carry the extra equipment necessary. His interest is focused more than 90 per cent on the ground. Further, only a few ants are tree ants. However such as nest in the ground and from the ground hunt for honey dew producing Homoptera on the foliage of bushes and trees usually hunt within range of a dust gun. In the north Homoptera are usually distributed up to 15 or 20 feet on aspens which trees are more or less deserted by them when the trees have developed above this height. In the south the large, very vigorous Alleghany mound building ant *Formica rufa exsectoides* collects honey dew from the stinking scale of yellow poplar (Lyriodendron) on trees fifty or more feet high, while certain species of Camponotus on oak appear never to contact the ground. Such species are so high other means of collecting have to be used. An agile young assistant with a saw and a rope to let down all dead limbs is very effective. A dust gun for such trees and such ant species to sample the ants on lower limbs before climbing might be useful. We have not tried such sampling.

The dust gun with 10% DDT or better yet 10% benzene hexachloride should be tried out. The latter has been recommended to the author for general bush collecting where a sheet can be spread on the ground. We have not seen it tried. The latter two dusts can be used freely with little danger to the operator but cyanide dust *must* be used down the wind. With the latter the collector could get a dose that would give him a thumping headache which might carry over into eternity.

Dusting for ants has two limitations. From Tennessee to northern Ohio it is effective probably because of the many species of shrubs and trees. Some valleys in eastern Tennessee have a hundred or more species of trees. These are fed on by equally numerous species of Homoptera. It is ant territory. On the Canadian border species of shrubs and trees are less numerous and in larger areas of pure stands. Many more are conifers and for some reason ants are not numerous in species on conifers. Perhaps the latter do not carry many Homoptera. The resins and oils of conifers may be unpleasant to Homoptera or ants or to both. A possibility is that the more primitive genera of Homoptera usually associated with conifers do not produce as much honey dew as the more highly evolved Homoptera

on broadleafed trees. The digestive systems of the higher aphids and scales are much more complex and are apparently evolved to a stage where they can use a larger and faster flow of sap. Dusting for ants appears to be hardly worth while in coniferous areas in the north. However the natives of eastern Tennessee say that the earliest bee honey crop of the spring comes from the "little bugs on the pine trees". Our bee experts, Professor W. E. Dunham and R. R. Reese, confirm this. Aphid honey dew is very local, more often found in the Allegheny Mountains, but is a nuisance dark honey about the large Green Lawn Cemetery of Columbus, Ohio, which is a great area of lovely and cherished conifers. Bee-keepers near the cemetery have had to abandon bee-keeping or move their hives to a greater distance.

The second limitation is the fact that this type of collecting catches only field workers, and of these usually exclusively one caste of a species, minors or majors. The character of males and queens and the structure of the nest are not found. For three summers we collected a minute dark *rufa* working on low bushes, milkweed and other herbaceous flora, one we supposed was an undescribed *microgyna* and could not find a nest. Eventually we found its nest which on being opened proved to be the large *Formica rufa clivia* Creighton. We had been collecting the minors all the time in nests of the majors but had been identifying the nests by the large red majors and ignoring the minors which operated by themselves on honey dew in pure groups of the minor caste. Enough has been said to indicate the basic necessity of collecting ants in long series from known ants. Otherwise ant taxonomy develops headaches. However dusting for ants in trees does uncover species which appear seldom to contact the ground and should not be overlooked. Such collecting can be operated with the least over-all expense of time by a Hemipterist or other friend who by necessity does collect some type of tree insect. Ant faunas are at present so little known especially in areas unexplored for ants that the myrmecologist spends his time most profitably on ground and tree trunk forms.

4. *The Economic Entomologist and his light trap and bait.*—In Ohio we have added a genus and at least two species to the Ohio list from queens taken in light traps. Certain species of the *curvispinosus* group of *Leptothorax* have mating flights at night, when thousands of them will fly to a lighted sheet. In Ohio work was done with permanent light traps with a funnel and collecting bottle where ants were mixed with beetles and other trapped insects. We have forms of this group of *Leptothorax* and an undetermined species of *Colobopsis*, rare this far north, taken in such light traps by Doctor C. R. Neiswander of the Wooster Experiment Station who was scouting the state for pests. Unfortunately the weak males fly less often to light. The catches are almost one hundred per cent queens.

The use of collectors interested in bush and tree insects *is obtained as a favor*. No collector can collect effectively for any length of time outside of his own group. He overlooks his own group. According to authorities on human behavior, a favor freely given *and accepted* calls for an equal favor in return. The writer saves all beetles for the Coleopterist. These can be preserved in one drahm vials of 70 per cent alcohol along with the ants, sorted out later and presented with proper gracious words and gestures. Such a tie-up between two collectors is well worth while and becomes increasingly profitable to each.

For the collector of Hemiptera for some reason the tie-up is less effective. The ant collector too often brings back widely spread common species.

A PRELIMINARY STUDY OF THE EFFECT OF DDT ON APHIS MAIDIS FITCH AND ITS INSECT ENEMIES WITH PARTICULAR REFERENCE TO APHIDIUS (LYSIPHLEBUS) TESTACEIPES (CRESS.)[1]

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The discovery of the "wonder killing powers" of DDT spurred economic entomology. A great deal of experimental work was undertaken to determine the toxicity of DDT to various economic pests. Often DDT surpassed any other method of control.

Irregularities occurred, however. In some specific instances observations have been made of huge populations of insects or mites being built up after DDT treatment. The cause of this irregularity was not known and the question arose: Is DDT more toxic to the natural enemies playing an important role in the checking of pests than to the pest itself? If this were true, the biological cycle might be radically upset resulting in a large increase in the pest population.

Unfortunately, the trend in insecticide study has been to ignore the beneficial insect. Little attention has been given to the effect of various insecticides on parasites, predators, or pollinators. With these things in mind, a comparative study which would involve both the host population and its natural enemies was undertaken. This paper reports the observations of such a study.

During the summer of 1945, heavy populations of the corn leaf aphid, *Aphis maidis* Fitch[2] were present on field corn near Columbus, Ohio. There was heavy parasitism of this aphid by a braconid parasite, *Aphidius* (*Lysiphlebus*) *testaceipes* (Cress.).[3] This aphid and parasite were used as test insects. Many other biological enemies of this aphid including coccinellids, chrysopids and syrphids were present, and when possible, their activities were noted.

Biology of Host and Parasite

The biology of the principal insects involved in experimental work is reviewed briefly.

Aphis maidis Fitch

To quote from *Destructive and Useful Insects* by Metcalf and Flint:

> "Own knowledge of the life history of this insect is incomplete. In the North Central States, it appears in the corn fields about midsummer. In the South the insect multiplies rapidly and does its greatest damage in the winter months. Of the females, only the winged and wingless ovoviviparous

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[1]From a thesis submitted to the Graduate School of the Ohio State University in partial fulfillment for the Degree of Master of Science, this paper reports studies made by the author while employed by the Bureau of Entomology and Plant Quarantine, Division of Truck Crops, Columbus, Ohio. Grateful acknowledgment is made to Dr. Neale F. Howard, in charge of the laboratory, and to Dr. Dwight M. DeLong, of the Ohio State University, for their kind assistance in making this study.

[2]Determined by P. W. Mason.

[3]Determined by C. F. W. Muesebeck.

forms are known. Males have been noted only very rarely and the egg-laying true females have never been found. No observations have been made on the winter stages in the northern states, and it is not known whether this species passes the winter in the egg stage in this section or whether it migrates up from the South during the spring and early summer. . . . The number of ovoviviparous generations produced in a year varies from about 9 in Central Illinois to as many as 50 in southern Texas. The insects feed until they are killed by a heavy frost, or the drying up of their food plants."

This insect prefers sorghums, but may be found on corn, barley, sugar cane, millet, broomcorn, Sudan grass and many other plants of the grass family.

The corn leaf aphid is destructive to corn by feeding on the tassel and silk and coating them with honey dew which seriously interferes with pollinization of corn. Also, great numbers of corn earworm moths may be attracted to the honey dew on the ears. When corn is infested by this insect, numerous greenish or greenish-blue aphids appear in the curl of the leaves or upper stalk; sometimes they may entirely cover the leaves.

Aphidius (*Lysiphlebus*) *testaceipes* (Cress.)

A. testaceipes (Cress.) was chosen for a specific study because of its very large numbers in the field. In many instances 100% parasitism of the aphid host occurred.

It has been found that the life cycle of this insect takes from 7 to 15 days in passing from egg to adult during August and September (Webster and Phillips, 1912). The females begin ovipositing under favorable conditions within a few hours after emerging from the host. The oviposition period lasts from three days to a week depending upon temperature. The females may live and oviposit for five or six days in warm weather. This parasite is not active at a temperature much below 56° F. Aphids begin to reproduce at a temperature at or slightly below 40° F., allowing considerable damage to be done during temperatures at which development of this parasite is retarded.

Field Testing

Methods—

A survey of corn fields showed the heaviest infestations of the corn leaf aphid to occur on the outside edges of each field. This suggests that the aphids came to the corn from some border weeds and gradually worked their way toward the middle of the corn planting.

Infested corn plants within the first few rows of the field were classified as having heavy, medium, or light infestations. Plants having heavy infestations were selected for treatment. Each treatment was replicated four times, and each plot consisted of one corn plant. The insecticides were applied with hand knapsack sprayers and dusters.

Cages—

Cages were constructed and placed over the tassels or upper parts of the stalks after treatment. These cages were made of a fine mesh cheesecloth and constructed with sleeves at either end which were tied to the stalk. Cages used in field experiment 1 were constructed with a celluloid frame (see Cage 1, figure 1). In field experiment 2 the cage was simplified (Cage 2, figure 1). The celluloid frame was dispensed with and the cage was kept from collapsing by the pressure which the corn tassels exerted against the walls from within. Easier to construct, it proved to be as satisfactory as cage 1.

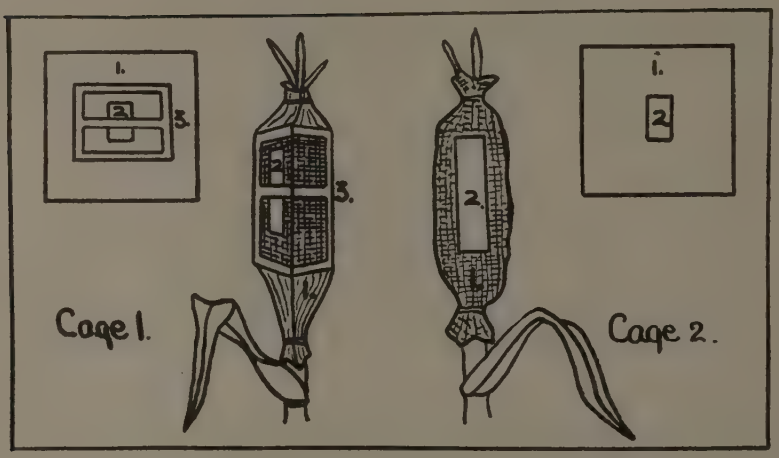


FIGURE 1. Construction of Cages, Field Experiments.
1=cheesecloth covering, 2=celluloid window, 3=celluloid frame.

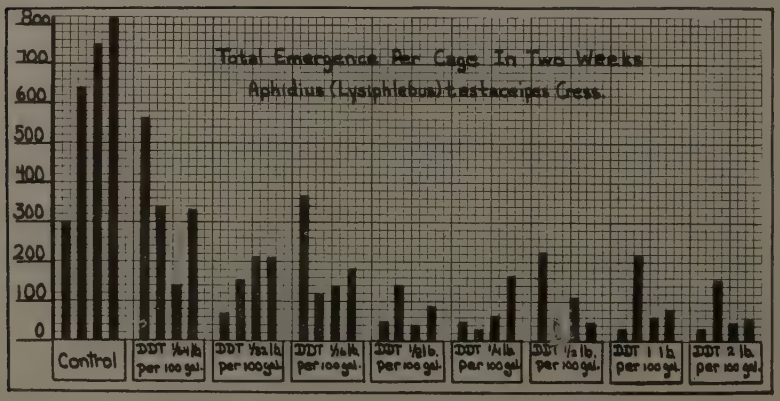


FIGURE 2. Parasite Emergence, Laboratory Experiment.
Histograms show total emergence for each cage (four cages per treatment).

INSECTICIDES—

For dosages used in each test, see Plates I, II, and III. Field experiment 1 was a test involving several formulae using different solvents. Field experiment 2 was based on concentrations of DDT from one formula using the same solvent.

The DDT (2, 2-bis (p.-chlorophenyl) —1, 1, 1-trichloroethane) used in suspension was received from the Geigy Company (G.N.B.A. mix 517) and consisted of 99.2% DDT. Stock formulae were prepared as follows and diluted to the desired concentrations:

DDT Benzol Formula:

DDT, 4 lb.; benzol, 1 gal.; B1956, ¼ pint.

DDT IDM #160 Formula:

This formula was received from R. D. Chisholm (Insecticide Division, Bureau of Entomology and Plant Quarantine), Moorestown, New Jersey. DDT, 1 lb.; Triton x 100, 1 lb.; Span 20 (sorbitan monolaurate—a product of Atlas Powder Company), 1 lb.; mix in enough acetone to make one gallon of stock solution.

DDT Kerosene Formula:

DDT, 5 parts; kerosene (commercial), 91 parts; B1956, 4 parts. On the dust plots, a Geigy 10% dust diluted in pyrophyllite was used.

For comparison with DDT, two other recommended aphicides were used.

(1) Nicotine-rotenone dust consisting of 1% rotenone to equal parts of sulfur and tobacco dust. (Bureau of Entomology and Plant Quarantine recommendation.)

(2) Black Leaf 40 at the rate of ¾ pound Black Leaf 40 per 100 gallons of spray.

DATA—

Aphid populations in the field were often so huge that they nearly overlapped covering every available space on a leaf, stalk or tassel. Due to the difficulty and lack of time and help to make actual counts, the investigator set up a scale, classifying the relative size of the population as very heavy, heavy, medium heavy, etc. Only living aphids were considered.

The parasite population was classified in the same manner with these exceptions. Both the number of adult parasites which had emerged and the number of parasitized aphids were considered.

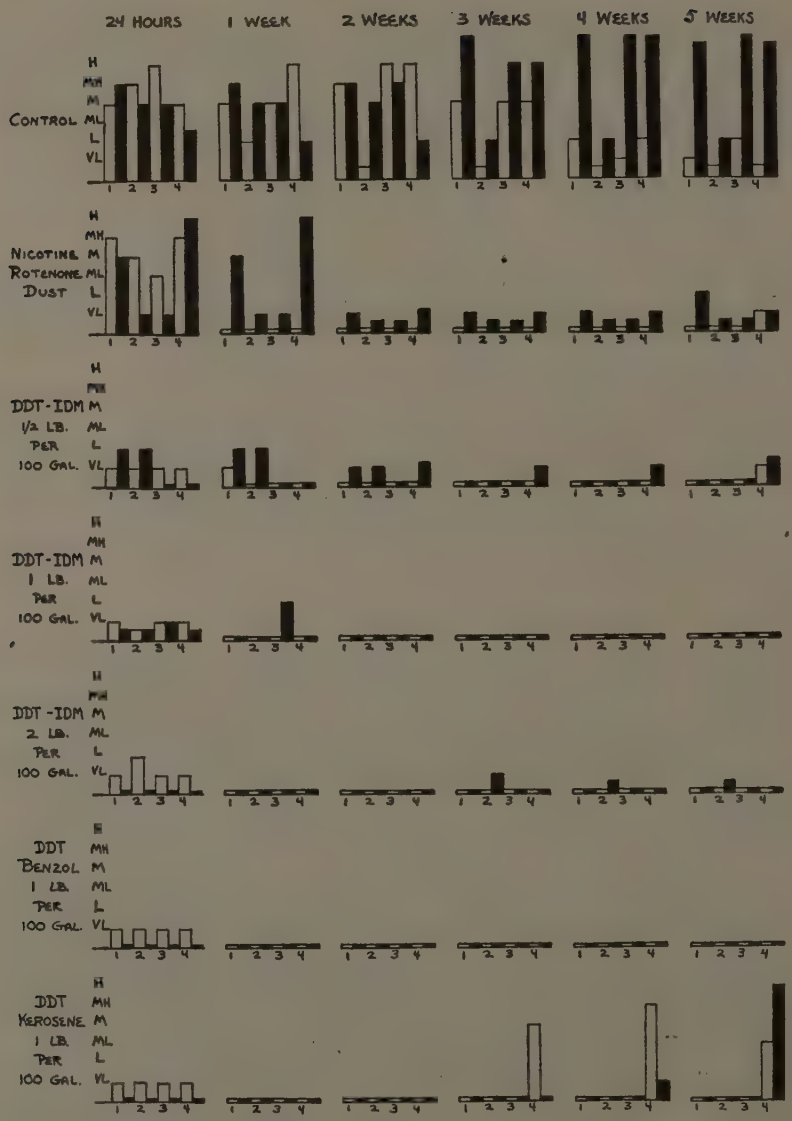
FIELD EXPERIMENT 1—

Data were recorded twenty-four hours after treatment and then once a week for a period of five weeks (see Plate I). The data plotted in the histograms on Plate I show that twenty-four hours after treatment both aphid and parasite populations of all DDT treated plots were greatly reduced. The control of the aphids at first appears better with DDT than with nicotine-rotenone dust. But, one week after treatment, the data show a disappearance of the aphid population on the nicotine-rotenone dust plots with the parasite population remaining higher than on any of the plots treated with DDT.

An irregularity appeared on #4 plot of the DDT-kerosene emulsion treatment. After the third week, the aphid population rose very rapidly. Those parasites which had not been exterminated by DDT staged a come-back that was noticeable the fourth week and was lowering the aphid population in the fifth week.

FIELD EXPERIMENT 2—

Data were recorded and analyzed in the same manner as in experiment #1 with slight variations. Observations were made twenty-four hours after treatment

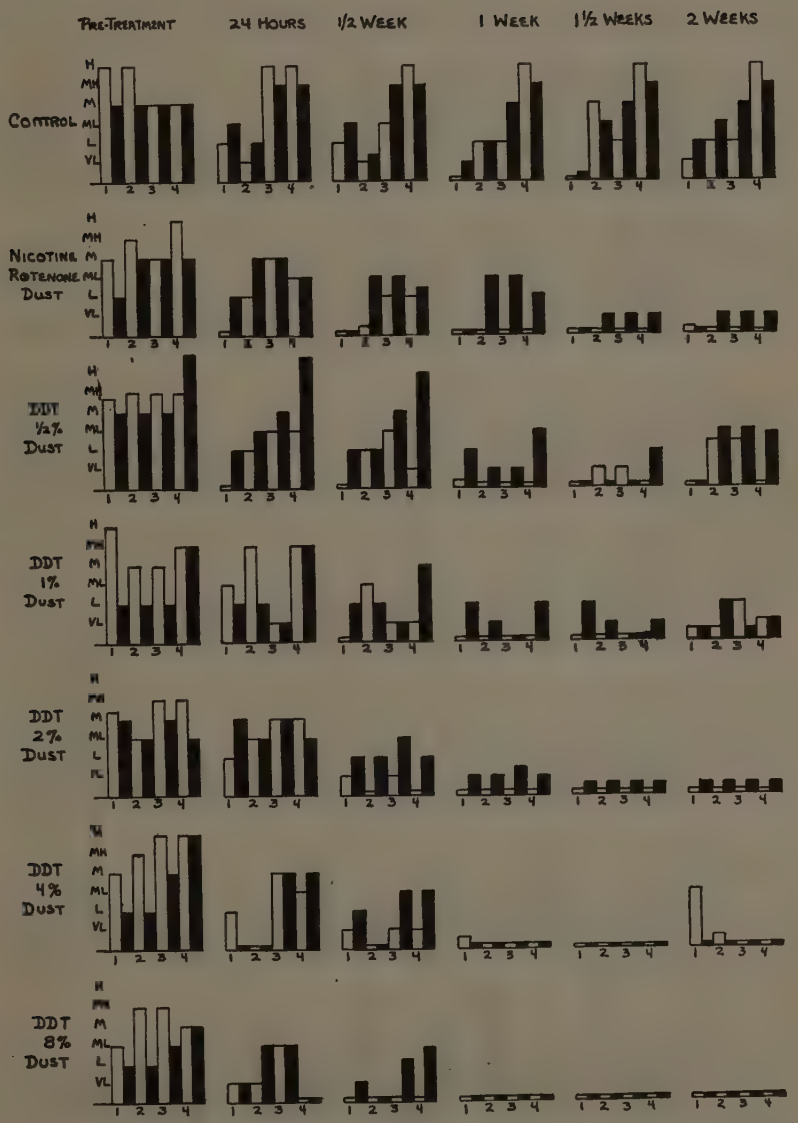


FIELD EXPERIMENT 1—PARASITE AND APHID POPULATIONS

Black = parasite, *A. testaceipes;* white = aphid, *A. maidis*. H = heavy, MH = medium heavy, M = medium, ML = medium low, L = low, VL = very low. Replicated plots are numbered 1, 2, 3, 4 for each treatment.

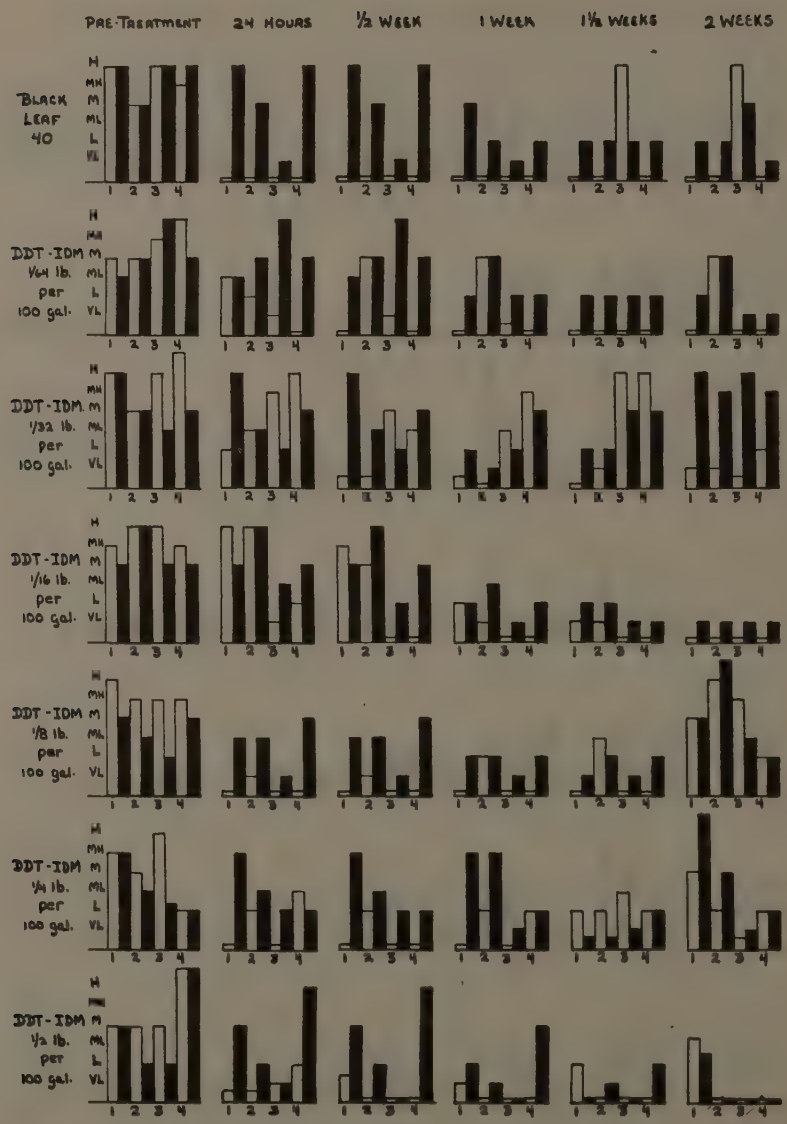
Effect of DDT on Aphis maidis
Mark Curtis Wilson

PLATE II



FIELD EXPERIMENT 2—DUST PLOTS, PARASITE AND APHID POPULATIONS

Black=parasite, *A. testaceipes;* white=aphid, *A. maidis.* H=heavy, MH=medium heavy, M=medium, ML=medium low, L=low, VL=very low. Replicated plots are numbered 1, 2, 3, 4 for each treatment.



FIELD EXPERIMENT 2—SPRAY PLOTS, PARASITE AND APHIS POPULATIONS

Black = parasite, *A. testaceipes;* white = aphid, *A. maidis.* H = heavy, MH = medium heavy, M = medium, ML = medium low, L = low, VL = very low. Replicated plots are numbered 1, 2, 3, 4 for each treatment.

and twice each week for a period of two weeks. This test was set up late in the season and due to corn harvest in mid-September, of necessity had to be terminated in two weeks.

In regard to the spray plots, Plate III illustrated good aphid control with Black Leaf 40. DDT treatments were at much lower concentrations than those of the previously mentioned experiment. Fair control appears to have been obtained with the highest concentration (½ pound DDT per 100 gallons of spray). In all cases, the parasites were not eradicated but rebuilt populations when the aphid population started to rise.

The dust plots illustrated on Plate II show that a 2% DDT dust and nicotine-rotenone dust were about equally effective aphicides. At concentrations below 2% the aphids reestablishing themselves commenced to rebuild their population. The 4% and especially the 8% dusts nearly eradicated both aphids and parasites within a week.

Laboratory Testing

Methods—

The plan was to set up a laboratory test to resemble field conditions. Corn tassels heavily infested with the corn leaf aphid which were largely parasitized by the braconid, *A. testaceipes*, were located in the field. These were cut and taken to the laboratory. They were then trimmed to fit cages described below, implanted in a can of moist sand, and treated. A pressure type compressed air paint sprayer was used to cover all parts of the plant adequately with DDT. The dosages used are shown on Plate IV.

Four replicates, each consisting of one plant, were used for each treatment. The plants were kept under artificial lights to simulate natural conditions.

Cages—

Cages were constructed of large celluloid strips which were rolled into cylinders and sealed with acetone making a cage eighteen inches high and six inches in diameter. A very fine mesh cheesecloth ceiling was fastened in the cage with acetone. The base consisted of an 8-inch clay flower pot saucer in which a layer of sand was placed.

Data—

Regular inspection of the cages took place each day for a period of two weeks. An actual count of the number of live parasites was made along with a count of the number of dead parasites. Predators were present and their various stages of development were noted along with the aphid host. Figure 3 illustrates the total parasite emergence per cage.

Aphids—

The aphids remained alive and in abundance on the checks for a week with the populations gradually decreasing after that time. Table I shows aphid kill 24 and 48 hours after treatment.

The decreasing size of the aphid population was probably due to adverse environmental conditions. While the experiment was in progress there was a sudden change in the weather. The days became very hot with an average temperature close to 80° F. The laboratory was not air-conditioned and the temperature could not be kept down to a more favorable constant for aphid development.

PARASITES—

Wherein the increase in temperature may have hindered aphid development its effect on the parasite population was the opposite. Parasites emerged in tremendous numbers and were very active.

For a record of the total parasites emerging from each cage see figure 4. The average number of parasites present each day during the period of two weeks has been plotted graphically (Plate IV). This series of graphs shows parasites emerging throughout the cages in all treatments. The lowest DDT concentration (¼ lb. DDT/100 gal.) shows a decidedly lower parasite emergence than the control. But, the highest concentration (2 lb. DDT/100 gal.), although low, also shows continued emergence throughout most of the period.

TABLE I

APHID MORTALITY—LABORATORY DDT TESTS

TREATMENT	CAGE							
	24 hours				48 hours			
	A	*B*	*C*	*D*	*A*	*B*	*C*	*D*
1. Control	O	O	O	O	O	O	O	O
2. DDT ¼ lb./100 gal	O	VL—	VL—	VL—	O	VL—	VL—	VL—
3. DDT ½ lb./100 gal	VL—	VL—	VL—	VL—	VL—	VL	VL—	VL—
4. DDT ⅛ lb./100 gal	VL—	VL—	VL—	VL—	VL—	VL—	VL—	VL—
5. DDT ⅛ lb./100 gal	VL—	VL—	VL—	VL—	VL—	VL—	VL—	VL—
6. DDT ¼ lb./100 gal	VL—	VL—	VL—	VL—	VL	VL	VL	VL
7. DDT ½ lb./100 gal	M	L	MH	M	M	ML	MH	M
8. DDT 1 lb./100 gal	M	H	H	M	MH	H	H	MH
9. DDT 2 lb./100 gal	H	H	H	H	VH	VH	H	VH

A, B, C, D=Cage replicate; O=Zero, VL=Very low, L=Low, ML=Medium low, M=Medium, MH=Medium heavy, H=Heavy, VH=Very heavy mortality, VL— =Less than VL.

It seems quite significant that a similar curve for all treatments should be shown by this series of graphs. The emergence reaches a peak and declines, falling down very low and then commences to rise again and reaches another peak in 6 to 7 days. From these comparisons and the fact that this parasite may complete its life cycle in 7–15 days (Webster and Phillips, 1912), it seems logical that the parasites surviving treatment were able to mate and oviposit with the resulting offspring emerging as adults at the time of the second peak shown on the graphs.

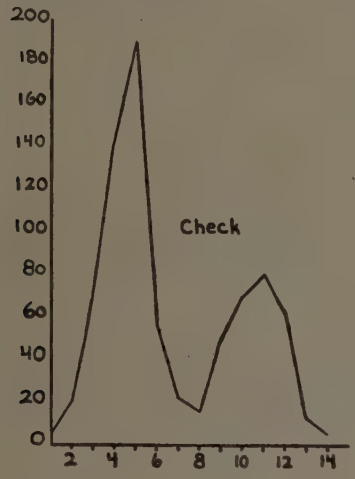
Certain paralytic actions were noted to occur to some of the parasites in cages treated with concentrations of one-fourth pound of DDT per hundred gallons and higher. Parasites would emerge, fly around, and as the data on Plate IV indicates, some would mate and oviposit. Others, as they walked on DDT treated leaves developed nervous reactions characterized by acute twitching of the legs and a gradual loss of equilibrium.

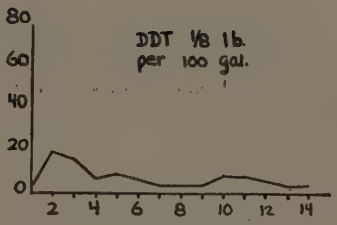
The number of moribund adult parasites increased rapidly in the higher concentrations of DDT. Parasites observed soon after emergence appeared normal until they had walked on the treated surface of the leaves for a short time.

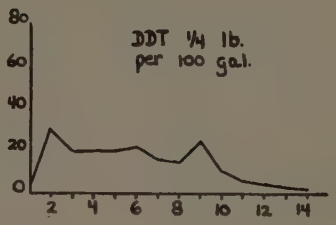
PREDATORS—

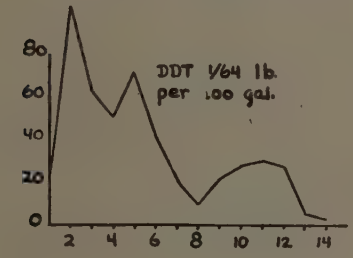
In at least one cage of each treatment (concentrations of one pound of DDT per 100 gallons of spray and under) examples of the following occurred.

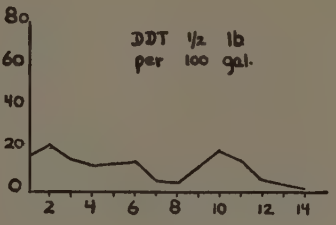
1. Coccinellid larvae pupated and emerged as adults.

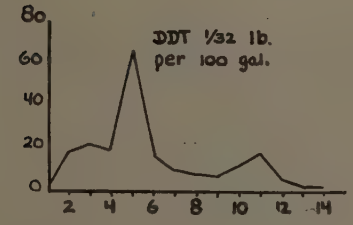


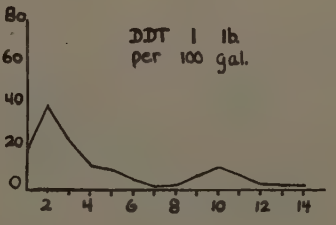


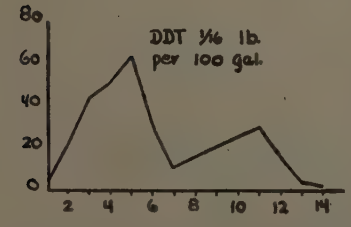


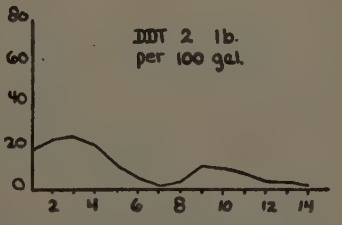












LABORATORY EXPERIMENT

Comparison of Parasite Emergence. The average total living parasites present in the four cages for each treatment is plotted per day as the ordinate; the days being the abcissa.

2. In one cage (DDT ⅛ lb./100 gal.) 5 coccinellid pupae emerged as adults. One pair was observed mating, and eggs were laid.
3. Aphis lions emerged as adult lacewings.
4. Syrphid larvae pupated and emerged as flies.

These observations were only scattered occurrences throughout the cages; consequently, significant conclusions cannot be drawn from them.

Summary

The biology of the corn leaf aphid, *Aphis maidis*, and its parasite, *Aphidius testaceipes*, is briefly reviewed. Field and laboratory experiments are reported of aphid infested field corn plants treated with DDT.

Population studies were made of the aphid and its parasite. A few observations on predators are listed.

In field tests, data taken 24 hours after treatment showed that DDT sprays were more effective against the corn leaf aphid than a nicotine-rotenone dust. One week after treatment nicotine-rotenone dust plots showed the same relative number of aphids killed as did DDT plots, but a lower relative number of parasites killed. One treatment of DDT did not eradicate the parasites unless the aphids were eliminated.

Further observations indicated that:

(1) *A testaceipes* was susceptible to DDT at the lowest concentration used (¼ pounds DDT per 100 gallons).
(2) *A. testaceipes* was not eradicated at the highest concentrations used (2 pounds DDT per 100 gallons) but emergence was greatly reduced.
(3) Laboratory experiments with *A. testaceipes* showed a similar emergence curve for all treatments. The parasite emergence reached a peak, declined nearly to zero and then rose to another peak in six to seven days. This parasite may complete a life cycle in six to seven days. This indicates that parasites surviving DDT treatment, emerged as adults, mated, and oviposited in DDT treated aphids. The resulting offspring of the parasites were able to complete another cycle.

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A PROGRESS REPORT OF THE CREEL CENSUS AT LAKES ST. MARYS AND LORAMIE, OHIO, 1946

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INTRODUCTION

To manage anything properly, and to check progress, it is necessary to make inventories and to keep records of the turn-over of the products. Business-like methods to check progress must be applied to fisheries management so that errors in methods may be eliminated and possible mis-spent dollars can be saved. Over 70 years ago, Ohio began her first efforts toward conserving or protecting her fisheries resources. Yet, it was not until the spring of 1946 that a program was inaugurated to obtain some facts on fish taken by the anglers at Lakes St. Marys and Loramie. It is impossible to state with any degree of accuracy what returns have been derived from past conservation practices or what practices should be continued, because we have no past records of the crop harvested.

The Creel Census project at these lakes was a part of a state-wide program to place management on a business-like basis and to learn something about the effectiveness of legal lengths, bag limits and closed seasons. Legal lengths, bag limits, and closed seasons were removed from these lakes in preparation for the Creel Census.

METHODS OF TAKING THE CENSUS

The census at both lakes was made by men employed especially for that purpose. Their work was supplemented by my help on holidays and Sundays. These Creel Census Takers were provided with prepared cards for recording the data, equipment for measuring and weighing the fish, for taking air and water temperatures, and for measuring transparency of the water. The censuses started on March 31 at Lake St. Marys and May 5 at Lake Loramie. Both censuses terminated on September 30, 1946. The census was conducted from 8:30 A. M. to 5:30 P. M. except on days when greater concentrations of fishermen occurred. On these days, the census was conducted from 8:00 A. M. until 7:00 P. M. Census returns were obtained for six days of the week, Fridays excepted, at Lake St. Marys and Tuesdays at Lake Loramie.

No attempts were made to contact the entire public. The Creel Census Taker at Lake St. Marys made one complete round of the lake daily, by auto, to visit all landings and areas at which fishermen concentrate. His contacts were random samples of all areas visited. At Lake Loramie, the Creel Census Taker confined the major portion of his activities to the lower end of the lake where most of the anglers are found. He traveled by boat. One trip was made each day, by auto, to the upper end of the lake to check anglers in that area.

The lengths of the fish were recorded to the nearest half inch and the weights of a majority of the specimens were determined by means of a Hansin scale and recorded in grams.

Information such as wind direction, wave action, air and water temperatures, transparencies, and type of weather were recorded daily.

Fishermen cooperation was solicited and creel census boxes, containing the necessary equipment for recording data, were provided at strategic points around the lake. Our results from voluntary returns were comparable to those obtained by Needham (Copeia No. 1, 1937) and described by him as, "very incomplete." No data from voluntary returns is included in this report.

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PHYSIOGRAPHY

Lake St. Marys: Lake St. Marys lies in the eastern part of Mercer and the western part of Auglaize Counties, Ohio. It is an artificial body of water, 100 years of age, impounded by damming tributary streams of the St. Marys and Wabash Rivers and flooding the dividing area between them. The lake covers possibly 11,000 acres and is approximately 9 miles long and 4 miles wide in its greatest dimensions. The drainage area is approximately 72,640 surface acres (Sherman 1932: 132), including the lake itself. Howe (1902: 293) credited the lake with having an average depth of 10 feet, when first constructed; but it seems that erosion of shores and incoming silt have greatly reduced the average depth. The shoreline is rather regular and partially wooded with the major portion of the woodlands on the south side. The shallow water of the south side is chiefly a cat-tail marsh. Clay banks and sand beaches are characteristic of the north shore. The bottom is predominately blue-grey silt with patches of sand and gravel along the shoreline.

The lake lies in an East-West axis and is fully exposed to the prevailing southwest winds. "Wind" seiches, causing a 12-inch rise in the water level at the east end of the lake have been observed. Heavy wave action churns the water thus causing considerable variation in the transparency during the same day. Heavy wave action also prevents the use of the greater portion of the lake for many days during the fishing season. During the 1946 season, the water level fell 30 inches below the spillway level, due to lack of rainfall and normal evaporation.

Lake Loramie: Lake Loramie lies in the northwestern part of Shelby County. It was formed nearly 100 years ago by damming Loramie Creek. The lake has a surface acreage of approximately 1500 acres. It is approximately 5 miles long and 2 miles wide in its greatest dimensions. The drainage area is approximately 69,120 acres in extent. No accurate data is available on the depth but it probably would not exceed an average of 5 feet. The shoreline is rather regular but greatly altered in appearance by the emergent vegetation. Large areas are filled with American Lotus (*Nelumbo lutea* (Willd.) Pers.) and long stretches of the shallow waters are filled with willows (*Salix* spp.). In general, the immediate shoreline is timbered; although the drainage area is in a high state of cultivation. The bottom is composed largely of a soft blue-grey silt-like soil with considerable sand and gravel along the shore of exposed areas.

The lake lies in a Northeast-Southwest axis and is thus exposed to the prevailing southwest winds. However, due to the small size of the lake and its well wooded shoreline, the wave action, at few times, is dangerous for boating. The large drainage area, compared to the small size of the lake itself, results in rapid and numerous changes in water level and turbidity.

ANALYSIS OF DATA

Fishermen Contacted: Creel census returns were obtained for a total of 7,740 fishermen at Lake St. Marys and 5,277 at Lake Loramie. This represents an average of 49.9 anglers contacted per day at Lake St. Marys and 34.5 per day at Lake Loramie. The most popular fishing months were May at Lake St. Marys and June at Lake Loramie. Approximately 31% of the fishermen who fished these lakes were present during these months. At both lakes the number of anglers gradually declined throughout the season. Anglers from 52 counties in Ohio, 5 other states and one foreign country were contacted at Lake St. Marys and anglers from 29 counties of Ohio and two other states at Lake Loramie. Approximately 31% of the anglers contacted at Lake St. Marys came from the counties in which the lake lies. At Lake Loramie, only 15.8% of the anglers came from Shelby County.

Hours Fished: Due to the large size of each lake it was impossible for one Creel Census Taker to contact the anglers at the end of their fishing day. The Census Takers, therefore, contacted fishermen in the act of fishing as well as those who had completed their day's fishing. The 7,840 anglers at Lake St. Marys had fished for a total of 21,937.37 hours or an average of 2.8 hours per individual. The 5,277 anglers at Lake Loramie fished a total of 16,358.7 hours or an average of 3.1 hours per individual. Yet, our records of those anglers who had completed their day's fishing show an average of 3.5 hours at Lake St. Marys and 3.7 hours at Lake Loramie. It is upon the average hours fished by those anglers who had completed their day's fishing that the following data has been based.

Catch: The anglers contacted at Lake St. Marys took 21,758 fish or an average of 2.77 fish per angler at the rate of .99 fish per hour of fishing. The fishermen contacted at Lake Loramie caught 10,119 fish or an average of 1.93 fish per angler at the rate of .65 fish per hour of fishing. The catch was composed of eleven species at Lake St. Marys and ten at Lake Loramie. Crappies, *Pomoxis annularis* Raf. and *nigo-maeulatus* (Le Sueer'), comprised the greater percentage of the fish taken at both lakes. The number of fish caught per hour of fishing was greatest in the month of September at Lake Loramie. It was almost identical for the months of June, July, and August at Lake St. Marys. On the basis of fish caught per hour of fishing, May was the least productive month at Lake Loramie and April at Lake St. Marys. Yet, these months ranked second in the number of anglers fishing at the respective lakes. At Lake St. Marys, 64% of the anglers contacted caught no fish and only 1.47% took more than the bag limit in force at other state waters. At Lake Loramie 34% of the anglers caught no fish and 9% took more than the bag limits effective at other state waters.

Crappies: At both lakes, crappies represented the major portion of the catch, 64.7% at Lake St. Marys and 40% at Lake Loramie. Crappie fishing began in late March at Lake St. Marys but not until early May at Lake Loramie. Crappie fishing was best at Lake Loramie during the week of June 10 to 16, but at Lake St. Marys became gradually better until it reached its peak in the middle of August. Crappies were again taken in increasingly greater numbers during September. The average length of the crappies checked at Lake St. Marys was 5.8 inches and weighed 1½ ounces. The average size of these checked at Lake Loramie was 6½ inches in length with a weight of 2½ ounces. Approximately 23% of the Lake Loramie crappies were over 7 inches in length but only 2.25% of those from Lake St. Marys were over 7 inches in length.

Bluegills—Lepomis machrochirus Raf.: Bluegills made up nearly 26% of the total catch at Lake Loramie but comprised only 2.69% at Lake St. Marys. Bluegill fishing reached its peak at both lakes during the latter part of June, and then dropped off during July and early August. Increasingly greater numbers of bluegills were taken at both lakes during the last few weeks of the census. The bluegills at Lake Loramie averaged 6½ inches in length and 2½ ounces in weight as compared with an average length of 5.55 inches and 2 ounces in weight at Lake St. Marys.

Bullheads—Ameiurus melas melas (Raf.) and *A. nebulosus nebulosus* (Le Sueur): Bullheads ranked third in number of fish caught at both lakes. They represented nearly 20% of the harvest at Lake Loramie and approximately 8.1% at Lake St. Marys. Most of the bullheads were brown bullheads locally known as "marble catfish." Bullhead fishing at Lake St. Marys was best in April and gradually but steadily decreased until the end of the census. At Lake Loramie, bullhead fishing improved steadily each month until it reached its peak in the middle of September. The average size of the bullheads caught at both lakes was approximately 8¾ inches; but those from Lake Loramie weighed 5¾ ounces as compared with an average of 4¼ ounces at Lake St. Marys.

Channel Catfish—Ictalurus lacustris (Walbaum): "Channels" ranked second in importance in the anglers catch at Lake St. Marys, comprising 19.86% of the total catch, but represented only 2.7% of the total catch at Lake Loramie. Channel catfish fishing at Lake St. Marys was best during June, but best in September at Lake Loramie. The average channel catfish checked at Lake St. Marys was 10¾ inches long and weighed 12 ounces as compared to an average length of 11¼ inches and 17 ounces at Lake Loramie.

Largemouth Black Bass—Huro salmoides (Lacepede): Approximately 3.26% of the fish caught at Lake Loramie were largemouth bass but only 1.18% of those taken at Lake St. Marys were of this species. Bass fishing was fairly consistent throughout the season. In spite of the lack of legal lengths and bag limits, the sportsmen returned to the lake 7.77% of the bass taken at Lake St. Marys and 5.39% of those taken at Lake Loramie. The bass creeled by the anglers ranged from 6½ inches in length to 21½ inches at Lake Loramie and 24 inches at Lake St. Marys. The average bass at Lake St. Marys was 14.6 inches in length and weighed 2 pounds and 14 ounces as compared with the average of 12 inches and 18 ounces at Lake Loramie.

TABLE I

Comparison of Lakes on Basis of Fish Caught Per Hour of Fishing

Water Area	State	Fish Per Hour	Date of Census	Authority
Mirror Lake....	Mich...	3.3	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Doyle Lake.....	Mich...	2.8	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Walsh Lake.....	Mich...	2.6	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Crooked Lake...	Mich...	2.5	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Cedar Lake.....	Mich...	2.2	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Cassidy Lake...	Mich...	2.0	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Greene Lake....	Mich...	1.7	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Waubesa Lake..	Wis.....	1.53	May 15-Sept. 25, 1939	(Frey & Vike 1941: 340)
Mill Lake.....	Mich...	1.2	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Fife Lake.....	Mich...	1.07	June 25-Sept. 30, 1934	(Eschmeyer 1939: 355)
Fife Lake.....	Mich...	1.0	June 25-Sept. 30, 1936	(Eschmeyer 1939: 355)
Fife Lake.....	Mich...	1.0	June 25-Sept. 30, 1937	(Eschmeyer 1939: 355)
Clear Lake.....	Mich...	1.0	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Lake St. Marys.	Ohio....	0.99	Mar. 31-Sept. 30, 1946	
Portage Lake...	Mich...	0.9	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Sugarloaf Lake..	Mich...	0.9	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Kegonsa Lake...	Wis.....	0.82	May 15-Sept. 25, 1939	(Frey & Vike 1941: 340)
Lake Loramie...	Ohio....	0.65	May 5-Sept. 30, 1946	
Chautauqua Lake.....	N. Y....	0.55	.....	(Moore 1937:)
Mud Lake.....	Mich...	0.5	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Waterloo Mill...	Mich...	0.4	June 25-Nov. 30, 1936	(Hazzard & Eschmeyer 1938: 638)
Foots Pond.....	Ind.....	0.28	June 25-Aug. 22, 1940	(Lagler & Lagler 1942: 112)

DISCUSSION

It is interesting to note that the counties, in which Lakes Loramie and St. Marys lie, supplied only a small percentage of the anglers contacted during the census. Montgomery County supplied the greatest number of anglers at Lake Loramie and ranked second at Lake St. Marys. The fact that 5% of the anglers contacted at Lake St. Marys were from other states does not speak ill of Ohio fishing.

The small size of Lake Loramie, and the concentration of the anglers at the lower end of the lake, enabled the Creel Census Taker to make a fairly accurate estimate of the daily total number of anglers using the lake. Practically all the

anglers could be counted by cruising around the lower end of the lake. All areas were visited at least three times per day.

The Creel Census Taker at Lake St. Marys estimated the number of anglers at each fishing area as he made his daily trip around the lake. Due to the fact that the average fishing time per angler was 3.5 hours, the Creel Census Taker could not have observed over one-third of the anglers fishing at any given point during the day. For this reason, his estimates have been multiplied by three to obtain the total number of anglers using the lake per day.

It is estimated that 136,311 or 13 anglers per acre of water, fished Lake St. Marys during the period of the census and that 17,701 or 12 anglers per acre of water fished Lake Loramie. Approximately 85% of the anglers at Lake St. Marys and 71% at Lake Loramie fished from the shore.

When compared on the basis of fish caught per hour of fishing, with other creel census reports, we find Lake St. Marys to be about average and Lake Loramie to rank rather low. (see table I)

The average number of fish caught per hour of fishing for the above 22 bodies of water is 1.26 or .3 above Lake St. Marys and nearly double that of Lake Loramie.

The estimated 136,311 anglers at Lake St. Marys fished a total of 377,088.5 hours. At .99 fish per hour of fishing, the anglers removed 472,317 fish from the lake during the period of the census. An idea as to the poundage of the fish caught is given by the following table.

TABLE II

FISH HARVEST AT LAKE ST. MARYS DURING THE PERIOD OF THE CENSUS

SPECIES	PER CENT OF TOTAL	TOTAL NUMBER	AVERAGE WEIGHT, OUNCES	TOTAL WEIGHT, POUNDS	POUNDS PER ACRE
Crappies	64.64	305,352.9	1.5 oz.	28,626.2	2.66
Channel Catfish	19.86	93,802.15	12 oz.	70,351.61	6.39
Bullheads	8.09	38,210.44	4.5 oz.	10,746.68	.98
Bluegills	2.69	12,705.33	2.0 oz.	1,588.29	.14
Largemouth Bass	1.18	5,573.34	46 oz.	16,023.35	1.45
Carp	2.76	13,035.95	13 oz.	10,597.96	.96
	99.22%	468,680.15		137,934.09	12.58

The estimated 17,701 anglers fishing at Lake Loramie fished 65,494 hours. At .65 fish per hour of fishing, they caught 42,591 fish during the period of the census. An idea as to the poundage may be obtained from the following table.

TABLE III

FISH HARVESTED AT LAKE LORAMIE DURING THE PERIOD OF THE CENSUS

SPECIES	PER CENT OF TOTAL	TOTAL NUMBER	AVERAGE WEIGHT, OUNCES	TOTAL WEIGHT, POUNDS	POUNDS PER ACRE
Crappies	39.93	17,007	2.5 oz.	2,657.3	1.78
Bluegills	25.9	10,971	3 oz.	2,057.1	1.37
Bullheads	20.14	8,578	5.7 oz.	3,055.9	2.04
Largemouth Bass	3.26	1,388	18 oz.	1,562.	1.04
Channel Catfish	2.71	1,194	14 oz.	1,044.9	.69
	91.94	41,136		10,377.2	6.92

When Lakes Loramie and St. Marys are compared to other bodies of water on the basis of pounds of fish caught per acre, we find they compare favorably with all but the well managed lakes checked by the Illinois Natural History Survey. The following compares the harvest in pounds per acre as shown by Creel Census reports on widely scattered bodies of water in the Middle West.

Water Area	State	Pounds per Acre	Authority
Fork Lake	Illinois	162	(Bennett, Thompson & Parr)
Unnamed Lake	Illinois	98	(Thompson 1941: 211–212)
Unnamed Lake	Illinois	80	(Thompson 1941: 211–212)
Shoe Lake	Indiana	46	(Ricker 1942: 223)
Muskellunge Lake	Indiana	27.5	(Ricker 1945: 343)
Eight Crow Wing Lake	Minnesota	19.1	(Eddy 1941: 39)
Waukesa Lake	Wisconsin	13.5	(Frey & Vike 1941: 344)
Lake St. Marys	Ohio	12.58	
Yellowwood Lake	Indiana	10.0	(Ricker 1945: 343)
Fife Lake	Michigan	10.0	(Eschmeyer 1936: 222)
Richter Lake	Wisconsin	8.6	(Elkins 1937: 307–312)
Lake Loramie	Ohio	6.9	
Delta Lake	Wisconsin	4.6	(Elkins 1937: 306–312)
Anderson Lake	Wisconsin	3.9	(Elkins 1937: 306–312)
Pike and Round Lakes	Wisconsin	2.8	(Elkins 1937: 306–312)
Deer Lake	Minnesota	2.64	(Eddy 1941: 39)
Island Lake	Minnesota	2.56	(Eddy 1941: 39)

The lack of fishing intensity accounts to a great extent for the small number of pounds of fish removed per acre from Lakes St. Marys and Loramie. If the shore fishermen at Lake St. Marys fished a strip 100 feet wide around the entire shoreline, there would remain over 10,000 acres of water to be fished from the 1,598 boats on the lake. This means 1 boat to approximately 7 acres of water. At Lake Loramie approximately 500 boat licenses were sold in 1946 or 1 boat to each 3 acres of water of the lake.

Fish have been stocked annually in Lakes St. Marys and Loramie as a part of Ohio's fisheries conservation program. A comparison of the following tables depict the correlation between stocking and the harvest.

LAKE ST. MARYS

Species	*Percentage of Fish Stocked*	*Percentage of Fish Caught*
Bluegills	58.61%	2.69%
Bullheads	25.04%	8.09%
Largemouth Bass	5.74%	1.18%
Crappies	4.43%	64.64%
Channel Catfish	3.77%	19.86%

LAKE LORAMIE

Species	*Percentage of Fish Stocked*	*Percentage of Fish Caught*
Bluegills	59.81%	25.9 %
Bullheads	28.04%	20.1 %
Largemouth Bass	4.32%	3.26%
Crappies	2.82%	39.93%
Channel Catfish	2.55%	2.71%
Perch	1.72%	0.

From the above tables it might appear that stocking is somewhat correlated with the fish harvest at Lake Loramie, but has no correlation with the harvest

at Lake St. Marys. Yet, over one-third of all the fish taken at Lake Loramie and nearly two-thirds of those taken at Lake St. Marys were crappies in spite of the fact that this species comprised less than 5% of the fish stocked. Only one crappie was stocked to 14 bluegills at Lake St. Marys but 30 times as many crappies as bluegills were caught. Approximately 2% of the fish stocked in Lake Loramie were perch but none were observed during the census. At both lakes the take of carp exceeded 1% of the total catch but none have been stocked according to the records of the Ohio Division of Conservation and Natural Resources. According to the "old-timers," who commercially fished Lakes Loramie and St. Marys, there was a time when few crappies were found in these lakes. Had crappies been stocked at the time of their increase, these plantings would have received credit for their increase in numbers. A lack of stocking over a period of 10 years shows no decrease in the numbers of crappies in either lake. The elimination of all stocking from these waters for a period of years is needed to provide necessary "clincher" data on the efforts of stocking.

Test nets were operated in each lake in April, June, and August. In spite of relaxed regulations, the test nets took 31 fish per hour exclusive of the shad, at Lake Loramie and 44 at Lake St. Marys.

SUMMARY AND CONCLUSIONS

1. A Creel Census was conducted at Lake St. Marys from March 31 to September 30, 1946, and at Lake Loramie from May 5 to September 30, 1946.
2. Anglers averaged catching .99 fish per hour of fishing at Lake St. Marys and .65 fish per hour at Lake Loramie.
3. When compared on the basis of fish caught per hour of fishing, with other lakes in the Middle West, St. Marys ranks about average but Lake Loramie is low in production.
4. An estimated 477,088 hours of fishing at Lake St. Marys yielded 472,317 fish weighing 137,934 pounds or 12.58 pounds per surface acre of water.
5. An estimated 17,701 anglers at Lake Loramie fished 65,493.7 hours and caught 42,591 fish weighing 10,384.8 pounds or approximately 7 pounds per surface acre of water.
6. The catch per hour had no correlation with the number of anglers fishing.
7. Although some apparent correlation between stocking and harvest may be noted at Lake Loramie, the species taken in greatest numbers (crappies) is one stocked in smallest numbers.
8. No correlation can be seen between the catch and stocking at Lake St. Marys.
9. In spite of bluegills being stocked in great numbers at both lakes, crappies are the dominant fish.
10. Only 1.47% of the anglers at Lake St. Marys and 9% of those at Lake Loramie caught over the bag limits in force at other state waters.
11. A bag limit at Lake St. Marys would have affected only one in each 67 anglers and one in 10 at Lake Loramie.
12. Legal lengths on crappies at Lake St. Marys during the summer of 1946 would have prevented the taking of the average size crappies (5.8 inches) or practically closed fishing for the season.
13. A large catch of breeder fish at both lakes in test nets, together with the small catch per acre by the anglers, indicates a large population of breeders remaining after a season of relaxed regulations.

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